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THE CONTRIBUTION OF ORTHOPAEDIC SURGERY TO THE LISTER ANTISEPTIC METHOD *

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A knowledge of the history of orthopaedic surgery should form the background of every clinical procedure and of every contribution to the literature of our specialty. Only in the light of historical perspective is it possible to formulate those fundamental assumptions which constitute the principles with which all methods and techniques in orthopaedic practice must comply.

We live in what has been called the "gadget age" and in a keenly competitive professional environment. In the desire to produce something different, procedures are often proposed which are clever in conception, but which fail to comply with rules that are fundamental. Every orthopaedic surgeon should be "good at gadgets", but he should not spend too much time, or too much ink and paper, in trying to persuade the rest of us to use his gadgets for things we can do better with our own. Moreover, in the selection of special technical methods of our own or others, their complete compliance with principles must always be the primary requisite. It is the failure to evaluate methods and techniques in the light of principles that leads to errors in the choice of apparatus and of operative procedures.

One of the simplest illustrations of disregard for a principle is that we often see unsatisfactory results in the treatment of club-foot because of failure to overcorrect the deformity. To correct, merely, is to neglect the fundamental principle that the establishment of a full normal range of motion is an essential of treatment. The maintenance of overcorrection by operation, splints, and shoes, until all the parts are soundly healed, involves compliance with a principle which may not be disregarded if good results are to be obtained. The details of technique may be different and interesting, but the fundamentals to be kept constantly in mind must always be the same.

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Hippocrates taught that "it is the first duty of the surgeon to do his patient no harm" and that "we should assist nature and not get in nature's way". It is the restoration of parts to normal relationship, the relief of deformity, the provision of surgical and mechanical devices for affording rest, and the alleviation and cure of disability that must characterize the work of the orthopaedic surgeon.

No recent phenomenon in surgical practice has emphasized so much the importance of adherence to fundamentals as our experience with the Lister antiseptic method. Lister's teaching gave us a new principle,—the exclusion of known and harmful infection from wounds. In the efforts to apply and improve the Lister method a large majority of surgeons have gone astray.

At a meeting of the British Medical Association in Dublin in 1867, Prof. Lister promulgated his new doctrine.[10] In some respects, it now appears to have been unfortunate that, in carrying out his technique, Lister employed carbolic acid and called his method the antiseptic system. Most of his followers have endeavored, unsuccessfully, to employ chemical antiseptics as a means of combating infection in wounds instead of recognizing that it was the principle of exclusion of infection that lay at the bottom of the Lister revolution in surgery.

At about the same time as Lister's original work, Hugh Owen Thomas, of Liverpool, was teaching a method of control of inflammation and infection which rested upon a different principle. He stressed the ability of the patient to recover from various bone and joint diseases under circumstances and conditions designed to favor only the most efficient employment of the patient's own defenses.

Regarding the Lister method, Thomas [18] said: "For some years previous to the introduction of the antiseptic method, I practised the open method and was well satisfied with the results obtained, but on the publication by Professor Lister of his successes, I at once commenced the practice of antiseptic surgery [this was as first taught by Lister, and included the carbolic spray] and continued to practise it for three years, with the result of being perfectly satisfied that its merits have not been over-stated nor the trouble necessary for carrying out the details exaggerated. I returned, however, at the end of that time to the open method, and have since laboured to improve it, so much so that I am emboldened to assert that the open method, in results and successes, is equal, if not superior, to anything to which antiseptic treatment has yet attained."

Thomas was quick to see that the Lister method which tampered with wounds and disturbed the patient violated the principle of repair by rest which was so significant to him. Thomas understood, as few before or since have understood, the importance of providing true physiological rest for the patient. He pointed out on many occasions the tendency of the patient toward spontaneous repair and said that nature always has a mode of operation if the surgeon can only understand and employ it. He recognized the teachings of Hilton, the great apostle of rest, but said

that Hilton's efforts at immobilization were inadequate because he did not know how to apply splints or apparatus without compression or constriction of the affected part.

That Thomas had a broad view of his own method is indicated by his statement [19]: "Men admired my splints as if I were a blacksmith, but the principles on which they were framed they never could see"; and, further, that of Sir Arthur Keith [7] in his sketch of Thomas: "We see that he carried out, just as he proposed it should be carried out in the treatment of intestinal obstruction, and as it never had been carried out before in cases of diseased hip-joint, a system of 'enforced, uninterrupted and prolonged rest'. 'A man', he said, 'who understands my principles, will do better with a bandage and broomstick than another can do with an instrument-maker's arsenal.'"

The open method to which Thomas refers was that devised by Bartscher and Vezin [2], who published a description of it in 1856. This method appeared to be opposed to the antiseptic method, but actually, when carried out under conditions of protection to the wound, was one which was sure to appeal to a man with Thomas' ideas in regard to the value of natural resources in the cure of disease.

In the open method, the wound surfaces or the diseased areas were bathed with the antiseptic and antitoxic solutions manufactured by the patient himself. This conformed to nature's design to rid him of undesirable organisms or toxins and to promote healing. Such a program implied the protection of the patient against washes, chemical antiseptics, frequent dressings, and other disturbances to which Thomas was so sincerely and vigorously opposed. It provided also for the escape of blood clot and other materials likely to remain inside the wound and to be subject to fermentation.

Due to a misunderstanding of the Lister idea, constant or intermittent irrigation methods have been encouraged. This plan goes back really to the time of Langenbeck [9] in 1839. To such disturbing methods orthopaedic surgeons, especially, should always take exception as did Thomas, on account of the damage to the wound and the wound area and the interference with suitable splinting and other devices for obtaining rest and protection for the injured part and the patient.

Orthopaedic surgeons should recognize that Thomas' success without the use of the carbolic spray and without the use of wet antiseptic dressings was partly due to the fact that he did actually protect the patient to some extent against invasion by organisms. This, however, he considered to be of secondary importance to the use of well-fitting and efficient apparatus for the care of the patient in correct position and at rest.

It is important to remember that there has always been a difference of opinion regarding wound treatment. Magati [13], Belloste [3], Paré [14], Hunter [6], Hilton [5], and Thomas [17], all argued for protection and infrequent dressings, but they lacked the knowledge of infection that came with the Lister revolution in surgery.

It seems a pity that the methods of Thomas and Lister could not have been combined at the very beginning. The inability of surgeons generally, and of surgery as a specialty, to realize the full benefits of the Lister method has been due to the failure to combine protection and rest with the Lister antiseptic method.

At the end of the War, in 1919, one misguided follower of Lister wrote that in a suppurating wound "*the principles of treatment* consist in a removal of the discharge by free incision, by large drainage tubes, by frequent irrigation with antiseptic lotions, and by the use of baths, fomentations, and compresses". It seems very sad to have these called "principles". Every technical item suggested involves a violation of principles as most of us understand them.

The degree of error into which we have been led in this direction is indicated by the following quotation from one of our standard surgical works [15] in 1918:

"Probably one of the most striking examples of the treatment of infected wounds which has resulted from this present war is that which has been evolved by Carrel of the Rockefeller Institute, and, at present, in charge of a hospital at Compiégne. In the period before this war commenced, and even in the earlier days of the conflict, the aseptic treatment of wounds was advocated. This soon proved inadequate, and various other ideas of treatment, some more or less theoretical, were advanced. It remained, however, for Carrel to apply in a scientific manner the treatment which had been advocated sixty years previously by Lister, namely, the treatment of infection by antisepsis."

That Lister did, in fact, tend in this direction is indicated by the following [12]: "And whenever discharge is considerable, it is essential that the dressing be of a kind which will not permit the development of septic organisms in it, although it be saturated throughout; and this can, I believe, only be attained by the use of chemical antiseptic substances.

"I have for some time past employed for this purpose a combination of the two cyanides of zinc and mercury, which appears to fulfil the requisite conditions of antiseptic efficacy and due storage of the agent in spite of free discharge, together with absence of irritating properties. Having already published on this subject, I will not detain the members of the Congress with details regarding it, further than to say that since the date of that publication Professor Dunstan, of the London Pharmaceutical Society, has devised means by which the substance can be prepared in a perfectly definite manner, and containing twice as great a percentage of the cyanide of mercury as that which we have hitherto used; and, as I have ascertained that the cyanide of mercury is the more important ingredient antiseptically, and also that its larger amount in Dunstan's material does not make the salt irritating, we may fairly regard the new preparation as an improvement."

The antiseptics suggested by Penhallow were iodine, carbolic acid, peroxide of hydrogen, and common salt. Thousands of others have been

tried in the same way,—even maggot extract! Such procedures, in disregard of principles, led to the alleged failure of the Lister antiseptic method during the War. In such treatment the employment of efficient splints and casts has always been impossible and the control of fractures and fracture fragments is entirely out of the question. Neither can anyone adhere strictly to the Thomas idea of rest in the treatment of compound fractures if weight and pulley traction are employed. The use of Thomas splints with supplementary suspension in Balkan frames, weights, and pulleys, and ice tongs and pins with elastic traction, constitutes a complete departure from the teachings of Thomas regarding requirements for rest. With Thomas' well-fitting hip and knee splints no such adjuncts were permitted or required. With the general adoption of the idea that frequent dressing of wounds is unnecessary, and that exclusion of infection is the point of real surgical importance in the dressing, provision for easy access to the wound and frequent disturbance of the patient becomes not only unnecessary but prejudicial in every way.

In fairness to Lister himself, it must be acknowledged that he recognized that there was a drift away from the principle which he had enunciated originally. This is apparent in an address which he gave in 1889[11]. He was recommending the use of the double salt of cyanide of zinc and mercury as having claim to favor as a germicide and for its inhibitory effect upon the growth of organisms. His final words must be given the most careful consideration: "I believe I happened to be the first to direct attention to the antiseptic agency of living structures, and there is, perhaps, no one who attaches greater importance to it than I do. Without it, surgery in former days would have been absolutely impossible. Still, I know too well from experience that it cannot always be trusted, and that the use of antiseptic adjuvants is in the highest degree important. . . ."

There has been a disposition since Lister's time to carry into the operating room and into the hospital wards methods of antiseptic dressing and treatment which are of obvious disadvantage and discomfort to the patient. Both laboratory workers and surgeons have failed to realize that germicides and so-called antiseptic methods developed in the laboratory must be adjusted to the patient's general welfare and to his ability to defend himself against the surgeon as well as against infection.

There are those who say that there is no disagreement as to the importance and the propriety of rest in the treatment of fractures or other injured or inflamed extremities. While rest is mentioned by nearly all writers on this subject, it is rarely employed in the sense that Thomas intended it should be. If one considers this attitude in the light of our introduction, it may be seen that Lister's original teaching did not involve any contradiction of the principle of rest. However, the so-called Listerian techniques—irrigation, tube drainage, chemical antiseptic dressings in wounds, and the like—are all, in fact, departures from or corruptions of the Lister method. In so far as they damage the wound surface or disturb the patient they violate important surgical principles, for the appreciation

of at least one of which (the protection of the wound surface against infection and damage by chemicals) Lister, himself, was chiefly responsible.

It is usual for writers on surgical methods of the present day to advocate rest for compound fractures, but they provide for the reduction of the fracture only (1) after the patient recovers from shock, (2) after the swelling subsides, or (3) not until the open wound has healed. That no rest for the injured part can be provided under any of the above circumstances should be obvious to anyone who understands the principles of either Lister or Thomas.

We may take as an example the trophic changes that occur in the hand or fingers in cases of injury or damage to the forearm. Circulatory and trophic changes in the median and ulnar areas appear promptly and are striking and characteristic if anatomical relationship is not promptly restored. Protection of the patient in such a position that lymphatic, circulatory, and neurotrophic functions are restored to the part is the obvious indication.

Reduction of all the soft parts, as well as of the broken bones, is necessary if all the functions are to be resumed. Only under such circumstances is it possible for the individual's natural defenses to operate so that there may be a physiological restoration of the area.

The lack of understanding of the principles worked out by Thomas has been so general that it is not uncommon to observe Thomas' own splints inaccurately or inefficiently employed, and to see them modified by joints, screws, nuts, bolts, and other adjustment devices to the point where adequate control of the limb and the patient is impossible. Not only is this so, but injured and damaged limbs are often placed in such splints before correct position has been obtained. Fracture fragments and soft parts may be so shortened or rotated upon each other as to destroy any possibility of normal physiological function by the nerves, lymphatics, blood vessels, and other soft parts. The truth is that any form of elastic traction represents a violation of the fundamental requirements of immobilization in correct length and position. It might appear that the time has now arrived when reduction of most factures and deformities at the time of operation and fixation in plaster or some other equally efficient device (if any) should be done routinely instead of resorting to any form of postoperative traction. That is, traction should be employed always as an operative rather than as a postoperative measure, and fixation (also at operation), in whatever form may be necessary, should give us complete postoperative control.

The advantage of exact anatomical reposition for fractures and for diseased joints has been demonstrated anew in recent years by the wide employment of direct fixation methods as taught by Lane [8], Albee [1], and others. Even with the obvious disadvantages and dangers of operative internal fixation, the results in fractures have been so good that many surgeons and patients have cheerfully assumed the additional risk of open operation. If such operations could always be done by those equipped

and experienced, the method might be endorsed without reservation. As a safer alternative to these open methods, it has now been demonstrated satisfactorily that we may obtain length and position in plaster-of-Paris by means of pins included in the cast. By this method, neither pressure nor constriction is necessary, and, when primary reduction has been obtained, loss of position cannot occur.

The technique of internal splinting by bone grafts has at times been carried out so successfully that external splinting is unnecessary. In those cases in which adequate fixation cannot be secured by means of the graft alone, improper motion at the point of fracture may occur. Disturbance of the parts because of loss of position should generally be provided against by the use of skeletal fixation (rather than traction) in plaster-of-Paris as already suggested. This is a method which is almost universally applicable.

These considerations of restoration to correct anatomical relationship and of maintenance in suitable position for rest and subsequent function are fundamental to the practice of all surgery, but to orthopaedic surgery in particular. The devotion of the orthopaedic surgeon to these fundamental needs of the patient is what I think Sir Robert Jones had in mind when he spoke, as he often did, of the "orthopaedic conscience". The attitude of a surgeon toward these principles implies a proper respect not only for the fundamentals of orthopaedic practice, but for the essential needs of the patient. Under such circumstances and conditions, the patient's requirements as to protection against damage from the outside as well as against disturbance of his physiological functions are much more likely to be appreciated.

This is what enabled Thomas and his followers, many of whom have been in the front ranks of the American Orthopaedic Association, to make their contributions to surgery what they are today. This is illustrated by such a teaching as that of Dr. Phelps [16] of New York: "A tuberculous joint is not a purulent one, because the bacilli of tuberculosis are not pyogenic. When the joint becomes purulent it is because pyogenic germs . . . produce the condition known as osteomyelitis, which is one of the most destructive forms of joint-disease. Sinuses leading to non-purulent tuberculous cavities are the highways through which purulent infection travels. Knowing this, why not prevent the multitude of sinuses by operating and protecting the discharges from infection? I think that we should."

It is in the practice of orthopaedic surgery as a specialty that surgeons have shown the greatest interest in maintaining at all times the patient's parts in correct anatomical relationship for function. This has been one of the first items for consideration in our attempts to arrest disease, to prevent deformity, to lessen disability, and to restore the patient to his normal status. Our interest in these matters has inclined us to pay especial attention to protecting the patient and his injured or diseased areas against infection, and we have observed that it is only by the combination of the methods of Lister and Thomas, and of the best contribu-

tions of other surgeons, and orthopaedic surgeons in particular, that these ideals can be attained. It must always be kept in mind, however, that methods and techniques must infallibly conform to principles in order to be suitable for general adoption. We have often been the first to observe that dressing and splint methods have failed to conform to such principles and that they are for that reason not only improper but injurious. It is often, therefore, by a conservative attitude toward innovations, and not by devising gadgets, that we may make our contributions to a more complete realization of the ideals and possibilities of modern surgery. What we must endeavor to do is to so adhere to the fundamentals of the Lister idea that the putrefactive organisms will be kept out of the wounds and that this shall be done by the simplest measures possible. At the same time, the exclusion of infection affords the orthopaedic surgeon the opportunity to employ other principles—such as the principle of rest—with greater efficiency. To correct and to prevent deformity and to secure and to preserve all the best features of form and function will always be the aims of orthopaedic surgeons and of the specialty of orthopaedic surgery.

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THE TREATMENT OF FRACTURE-DISLOCATIONS OF THE CERVICAL VERTEBRAE BY SKELETAL TRACTION AND FUSION *

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The cervical spine is particularly vulnerable to injury because of the weight of the head and the mobility of the cervical vertebrae. When tense, the neck muscles, with the powerful ligaments, provide considerable protection, but, when the muscle defence is relaxed, the unexpected application of even a slight force may cause severe injury.

Indirect violence of various types is the usual cause of serious injury, producing at times extreme deformity. Fracture-dislocations easily produced are also readily reduced by prompt and appropriate treatment. Reduction can be maintained by plaster and other supporting jackets, but recurrence of the deformity may develop shortly after the support is removed, or the deformity may gradually increase over a period of years unless more energetic therapy is provided.

These observations are not new ones, — various surgeons have written on the problem, which is an important one, for, with recurrence of the deformity, nerve-root or spinal-cord involvement may result. It is the vulnerability of the spinal cord which makes the recurring deformities of such grave significance. Immediate death, due to respiratory paralysis, is not infrequent when the deformity recurs suddenly in the upper cervical region. Sudden transient quadriplegia, due to slight trauma, coughing, or sneezing, has occurred in some of the cases in our series. Slow development of spinal-cord signs, just as significant but not as alarming, have occurred more commonly.

In the past four years there have been under our care thirty-six patients with injuries to the cervical vertebral column, and in twelve of these the skeletal, muscular, and ligamentous involvement was such that operative intervention and fusion were carried out. It is because of the satisfactory end results obtained by fusion that the following representative case reports, discussion, and conclusions are presented.

FUSION FOR FRACTURE-DISLOCATIONS IN THE UPPER CERVICAL REGION

In 1907 Corner, under the title of rotary dislocations of the atlas, reported twenty examples,—eighteen from the literature and two from

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† Authors' names are arranged alphabetically in this joint report.

his own practice. Death followed soon after the accident in two of the twenty cases. In six, it resulted after a period ranging from twenty-three days to many years. Post-mortem findings in eight cases revealed more than rotary dislocations in every instance. In six, the odontoid was fractured; in one, there was a lateral fracture of the atlas; and in another, the fifth, sixth, and seventh cervical vertebrae were broken. Omitting the two rapidly fatal cases, in none of the other six were there spinal-cord symptoms at first. Corner points out that the absence of spinal-cord symptoms after trauma to this region makes it easy to overlook or to fail to appreciate the significance of injury to these parts, and that sudden death or the later development of paralyses is the penalty for failure to evaluate properly such injuries.

The following case emphasizes the correctness of Corner's conclusions, but fusion has altered the prognosis which he advised should be guarded. Now the occiput is fused to the cervical vertebrae and the patient is safely restored to his usual activity.

CASE 1.* *Progressive Occipito-Atlanto-Axial Dislocation. Fracture of the Odontoid Process.* (See Figures 1-A and 1-B.)

Dr. V. L., at the age of forty-two, was thrown through the windshield of his car. Unconsciousness lasted for two or three days. He had sustained multiple lacerations about the face and the head, five broken ribs, and a hemothorax. As soon as he recovered consciousness he observed that the neck was stiff and there was crepitus on movement.

For months after the accident the neck was massaged. Always some limitation of motion was present and at times the discomfort was marked.

In spite of the constant stiffness and periodic pain, the patient carried on his general practice for sixteen years. On May 14, 1935, at the age of fifty-eight, he was attending an obstetrical case and instrumental delivery was necessary. As he was making traction, the forceps dislodged. He slipped forward and noted a sudden numbness and tingling in the finger tips of both hands and weakness of the arms and the legs. The numbness continued, and the weakness of the arms increased until he did not have enough strength to unscrew his fountain pen. The neck was not painful if he reclined. He could not remain in the erect position without some support to the head, because the pain became intense and the power in the arms diminished.

With the limited activity which the pain imposed, he carried on until August 1, when, following a sudden movement, he again became weak all over and every muscle in the body ached.

On physical examination, the neck was rigidly splinted. The upper cervical spines were more prominent than usual and tender. The deep reflexes were symmetrically present and active throughout. Of the superficial reflexes, all were normal except the great-toe movements. The tests of Gordon, Oppenheim, Chaddock, and Babinski all caused the great toe to move up. Muscle strength in both upper extremities was reduced and fine finger movements were awkward. Although the patient complained of some weakness in the legs, it was not great enough to show as he walked.

No objective sensory changes could be demonstrated anywhere. He complained of paraesthesia and hyperaesthesia in the hands, particularly in the finger tips, and volunteered the information that at times when he walked the feet felt as though thick, soft insoles were in his shoes. In spite of this, the vibratory sense and the sense of position were normal everywhere.

*Referred by Dr. Jean Saucier.

The lumbar manometric test showed a complete block and there were 51.4 milligrams of total protein per 100 cubic centimeters in the spinal fluid.

Dr. A. E. Childe reported on the roentgenographic studies as follows: "Stereolateral views of the cervical vertebrae show an anterior dislocation of the skull and the axis on the atlas with an associated fracture of the odontoid. The odontoid process lies about 1.5 centimeters posterior to its normal position. Views of the odontoid through the open mouth show its outline to be fairly regular. There seems to be some narrowing of the articulations between the axis and the atlas. There is also the appearance of old trauma to the fourth and fifth cervical bodies indicated now by hypertrophic bony changes."

Following the preoperative diagnosis of progressive occipito-atlanto-axial dislocation and fracture of the odontoid, decompressive laminectomy and fusion were carried out on August 15, 1935.

The posterior arch of the atlas was well forward, pressing on the dura. The spinal cord had been exposed below this through a unilateral laminectomy, leaving the spinous

FIG. 1-A FIG. 1-B

Case 1. Progressive occipito-atlanto-axial dislocation.
Fig. 1-A: Before operation.
Fig. 1-B: After operation. The posterior arch of the atlas has been removed and the bone grafts run from the occiput to the sixth cervical spine.

processes intact. Pulsations with respiration or heart beat did not take place until the posterior arch of the atlas was removed; they then began at once and jugular compression caused large amounts of fluid to pour out from above.

Bone for grafting was taken from the right ilium. With the Hudson burr openings were made in the occipital bone, one centimeter to either side of the midline and one centimeter above the posterior arch of the foramen magnum. Through these openings, the dura was separated from the skull and protected while small drill holes were made. The pedicles of the first cervical vertebra were drilled and drill holes were placed through the spines of the cervical vertebrae. Through the various drill holes were passed ligatures with which the parallel bone grafts were tied to the cervical vertebrae and to the occiput. The parallel bone grafts extended from the occipital bone to the level of the sixth cervical spine. Rustless-steel wire, introduced by Babcock, was the suture material used to tie the grafts in place and to close the muscles in layers over them.

When the fusion was completed, the patient was transferred to his bed, and, through small burr holes in the skull, heavy rustless-steel wire sutures were passed, so that immobilizing skull traction would be possible until wound healing was complete and an immobilizing cast could be applied.

Nine weeks after operation the patient was discharged from the hospital, wearing a modified Minerva cast and walking. Lumbar manometric tests showed no evidence of block. Plantar reflexes were in flexion. Power in the hands had returned and the paraesthesia and hyperaesthesia of the fingers had disappeared.

Five months after the operation he was doing limited practice, wearing a neck support. After six months, all support was removed. He gradually increased his work until at the end of one year his activity had been fully resumed. On the first anniversary of the operation he made complete rounds with the surgical staff, occupying a period of four hours, and was not overfatigued. He cannot rotate the head and this hampers him in conversation and in traffic. This is now the only disability which he has. Roentgenograms show that the fusion is solid from the occiput to the sixth cervical vertebra.

Kahn and Yglesias have reported the history, findings, and treatment of an almost identical case. In their case, it was also necessary to remove the posterior arch of the atlas to decompress the cord, and the bone grafts were taken from the ilium. Their patient was restored to complete activity and felt that he was in no way handicapped by the fusion. The problem in such patients is similar to that of lumbar spondylolisthesis and the term "cervical axial spondylolisthesis" might be used to describe it.

CASE 2. *Fracture through the Base of the Odontoid Process with Backward Displacement.* (See Figures 2-A, 2-B, 2-C, 2-D, 2-E, and 2-F.)

F. P., aged fourteen, was referred by Dr. J. H. Mason of Lachute, Quebec, on July 25, 1935. To Dr. Mason's skillful supervision in transporting him to the hospital, the lad owes his life. On the afternoon of admission, he had fallen backward off a load of hay, striking the back of the head. He did not lose consciousness; he heard a loud crack in his head, the arms and legs were numb, and all power was lost. After a short period, he was able to move the legs a little and later could wiggle the arms a bit.

On admission, the most marked symptoms were pain and hyperaesthesia in the distribution of the second and third cervical dermatomes and pain in the neck. The patient screamed with pain caused by the lightest touch or a current of air striking the upper neck or chin and would not talk because movements of the lips or chin shifted the skin in the upper cervical region and caused pain. Any neck movement caused severe pain and gentle palpation was very painful. There was no obvious deformity.

The tendon jerks were hyperactive in the arms and legs; the abdominal reflexes were obtained with difficulty; the cremasterics were absent; plantar stimulation caused upward movements of the great toe on both sides.

The arms and legs were very weak, although no complete paralysis of any muscle group was found. Breathing was almost entirely thoracic.

Below the second and third cervical vertebrae, where the hyperaesthesia and spontaneous pain were so striking, there was complete loss of pain and hypaesthesia for touch over most of the right arm and slight hypaesthesia for all forms of sensation on the trunk up to the fourth thoracic dermatome.

FIG. 2-A

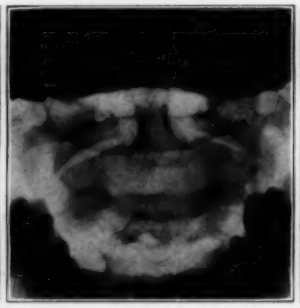

FIG. 2-C

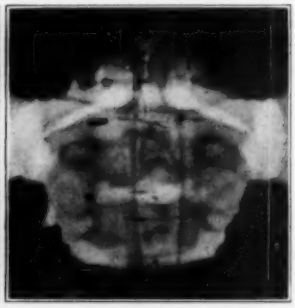

FIG. 2-E

FIG. 2-B

FIG. 2-D

FIG. 2-F

Case 2. Fracture through the base of the odontoid process with backward displacement.

Fig. 2-A: Film taken through the mouth immediately after admission, showing the laterally tilted odontoid and fracture through the base.

Fig. 2-B: Lateral view on admission. The odontoid is tilted back.

Fig. 2-C: Film through the mouth, taken immediately after traction was applied. The odontoid is now in the midline.

Fig. 2-D: Lateral view immediately after traction. The odontoid is vertical. The rustless-steel wire sutures through burr holes are in place and to these traction had been attached.

Fig. 2-E: View through the mouth after fusion. Reduction has been maintained and the parallel bone grafts are in place.

Fig. 2-F: Lateral view after fusion. The odontoid alignment is normal. The grafts extend from the first cervical vertebra to the fourth.

Both the lateral roentgenograms of the neck and the anteroposterior roentgenogram through the mouth showed a fracture through the base of the odontoid process.

Under local anaesthesia, with a Hudson burr, small openings were made in the skull into which heavy rustless-steel wire sutures were inserted, enabling skeletal traction to be applied.

Just as soon as the traction was applied, further roentgenograms were taken; these showed the odontoid in good position. The patient was very much more comfortable with the immobilization which traction provided and could be turned without pain. Lumbar manometric tests showed no block.

On August 17, with traction still on, the cartilages of the articular facets in the upper cervical vertebrae were curetted away. A curved piece of rib was removed and split, and the halves were laid parallel to each other—one on the right and one on the left side of the cervical spines—in contact with the laminae and tied in place with rustless-steel wire sutures. It was hoped that a fusion of the first, second, third, and fourth cervical vertebrae would develop as a result of the procedure.

A modified Minerva cast was applied on September 4, and the skeletal traction was removed on that date. One week later the patient was allowed up and, as practically all signs had cleared up, he was permitted to walk. He was discharged from the hospital on October 17, 1935, a little less than three months after admission.

This lad returned to school in January, about six months after the accident. Roentgenograms, one year after operation, showed the odontoid in normal position and an apparently excellent fusion. His posture, that of a patient with a stiff neck, was excellent and, since only four cervical vertebrae were fused, he had an amount of mobility which caused him no handicap.

The impression that the odontoid once fractured never unites by anything but fibrous union has been handed along, due, perhaps, to the fact that deformities so often develop years after injuries to the upper cervical region, as in Case 1. In the last roentgenograms of the patient in Case 2 there seems to be bony union and we have the impression that with adequate reduction and immobilization this may be expected in most cases. We feel that this patient's prognosis is excellent and does not need to be guarded.

CASE 3. *Comminuted Fracture of the Anterior Arch of the Atlas and Dislocation of the Left Articular Facet of the Atlas.* (See Figures 3-A, 3-B, and 3-C.)

E. G., aged six, was referred by Dr. John Kershman on April 10, 1936. While playing, he was pushed off a stairway and fell backward, sliding down seven stone steps, striking the head or neck on each riser on the way down. He held the head rigidly, slightly rotated and tilted to the right and he would not bend the neck. He complained of pain in the neck and in the occipital region. Dr. Kershman had found that with pillows under the shoulders, allowing the neck to be hyperextended by the weight of the head, the neck discomfort and occipital pain disappeared.

From the neurological standpoint, the only abnormality found was hypaesthesia over the distribution of the second and third cervical dermatomes bilaterally. There was no spinal subarachnoid block.

Roentgenograms showed a comminuted fracture of the anterior arch of the atlas and a dislocation of the left articular facet of the atlas. There was a soft-tissue swelling in front of the injured vertebra, a point to which Dr. Childe has called attention in other similar cases. It is due to hemorrhage under the prevertebral fascia, which pushes it forward.

On April 15, 1936, the occiput and the laminae of the cervical vertebrae were exposed. The posterior arch could be freely moved on the left side, due to a false point of motion in the region of the left articular facet. No other obvious abnormality was noted.

A rib was removed and split longitudinally, and the halves were laid against the laminae of the first, second, and third cervical vertebrae,—one on the right and one on the left. Rustless-steel wire sutures around the posterior arch of the atlas anchored the parallel grafts at the upper limit. Through drill holes in the spines of the second and third cervical vertebrae, the grafts were held tightly to the laminae.

Skeletal traction was applied to the skull, using heavy rustless-steel wire sutures.

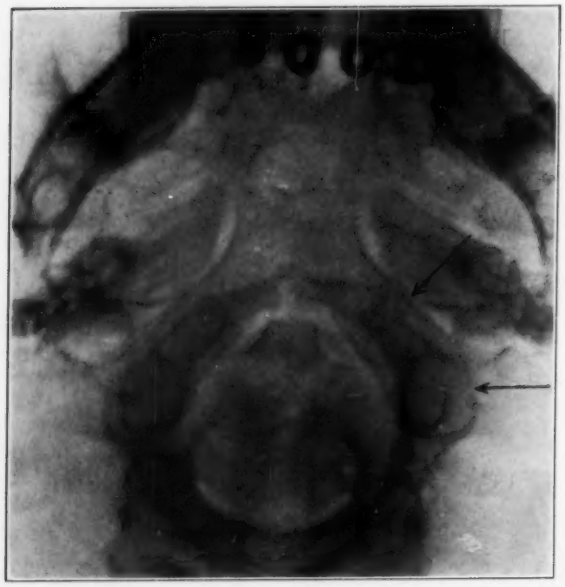

FIG. 3-A

FIG. 3-A, FIG. 3-B, AND FIG. 3-C

Case 3. Comminuted fracture of the anterior arch of the atlas and dislocation of the left articular facet of the atlas.

Fig. 3-A: Film of the base, showing the anterior arch of the atlas and the atlanto-axial articulations. Arrows point to the fractured arch and the dislocations of the left facet.

Fig. 3-B: Lateral view, showing abnormal posture and a retropharyngeal shadow due to hemorrhage.

Fig. 3-C: Lateral view after fusion. The parallel bone grafts are shown tied in position from the atlas to the fourth cervical vertebra. The retropharyngeal hematoma has absorbed.

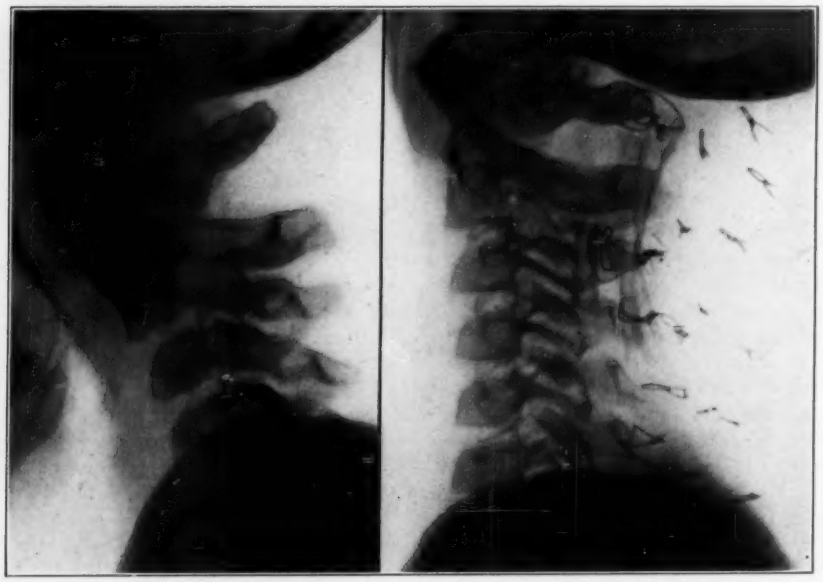

FIG. 3-B FIG. 3-C

On May 5, 1936, a modified Minerva collar was applied and the skeletal traction was then removed. The patient was discharged from the hospital, symptom-free neurologically, on May 16, 1936. He wore the cast for four months and then a compression collar for two months.

Ten months after the operation, he had no apparent disability. He held the head a little stiffly, but movements were surprisingly free. Roentgenograms showed the grafts well in place, fusing the first, second, and third cervical laminae.

One point deserves special emphasis in this case. The soft-tissue swelling in the retropharyngeal region was described by Dr. Childe in the first lateral views taken and the abnormal cervical curvature in these films made it seem from the roentgenographic standpoint that there had been an injury to the upper cervical spine. Roentgenograms taken through the open mouth did not disclose the nature of the injury and it was not until films of the base of the skull were obtained that the fracture was proved.

FUSION FOR FRACTURE-DISLOCATIONS BELOW THE THIRD CERVICAL VERTEBRA

The fact that late deformities develop after an entirely satisfactory reduction of fracture-dislocations and an adequate period of immobilization is not as surprising here as it is at the higher levels. The weight of the head acts on a longer lever and exerts more force on the injured part. It has seemed clear to us that the greater the ease and rapidity of reduction, the greater is the likelihood that later deformities may develop. When the injury is a complex one—in which bodies, articular facets, pedicles, and laminae are injured—reduction is often surprisingly simple. Even the weight of the head in hyperextension will at times bring about the reduction, and it is especially in these cases that fusion is indicated.

CASE 4. *Relapsed Fracture-Dislocation of the Fourth on the Fifth Cervical Vertebra.* (See Figures 4-A, 4-B, 4-C, 5-A, and 5-B.)

R. B., aged forty-two, referred by Dr. J. Boulay, Sutton, Quebec, came under supervision first on March 18, 1934. He had suffered a forward dislocation of the fourth cervical vertebra on the fifth, a fracture of the pedicle and the articular-facet elements between the fourth and the fifth vertebrae, and a fracture of the body and right lamina of the fifth vertebra.

He was almost completely paralyzed in both upper extremities and the legs were weak. The sensory level was at the fifth cervical segment. Reduction was promptly and painlessly accomplished with neck-halter traction and weights attached over a pulley, and the patient was immobilized in plaster. The neurological signs cleared up slowly; the lumbar manometric test showed no block and the patient was discharged three months after admission, walking and wearing a plaster cast and arm brace. The vertebral alignment was perfect.

Nine months later the deformity had relapsed in the cast. The patient had begun to have more neck pain and referred pain over the left shoulder. The roentgenogram showed a deformity more extreme than that present on the first admission and there appeared to be a solid fusion which we could not alter.

The patient was admitted to the hospital on June 19, 1935. Wire skull traction was applied with heavy weights, which brought about no change in the malunion. On June 24, 1935, he was operated upon and the cervical vertebrae were exposed. The laminae of the fourth and fifth cervical vertebrae over the apex of the deformity were removed and

FIG. 4-C

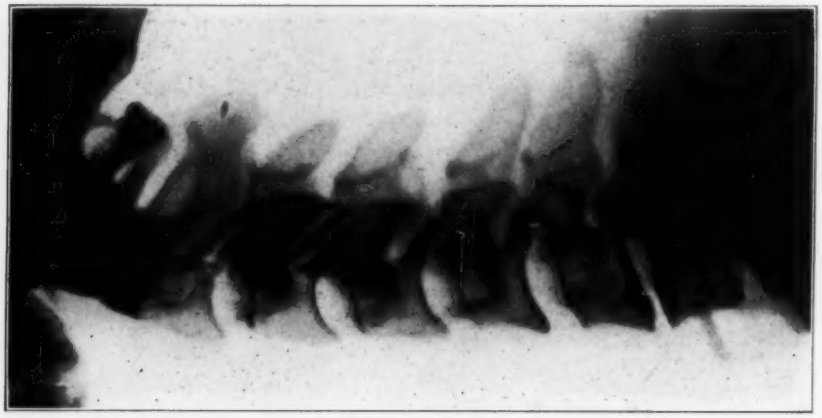

FIG. 4-B

FIG. 4-A

Case 4. Lateral films, showing:
Fig. 4-A: Initial deformity; Fig. 4-B: Reduction by traction; and Fig. 4-C: Satisfactory alignment after the cast was applied.

parallel tibial grafts were solidly moored from the second cervical vertebra to the seventh cervical vertebra with quite extensive bony contact. These furnished an excellent bony bridge. Seventeen days later, a head and neck torso plaster was applied and the traction wires were removed. The patient was discharged on August 27, 1935. The neck was protected for five months after the operation.

Twelve months after operation he was reemployed as a railway-crossing tender and his work has been satisfactory since that date. The roentgenograms show increased consolidation of the graft. There is extensive limitation of flexion and rotation. His endurance is good and the traffic does not bother him.

CASE 5.* *Old Fracture-Dislocation of the Fourth on the Fifth Cervical Vertebra with Advancing Spinal Compression.* (See Figures 6-A, 6-B, and 6-C.)

K. S., aged thirty-eight, struck his head on August 18, 1935, while swimming. He rolled on his back, was conscious, but could not move. After two or three days in another hospital, motion in the limbs gradually improved. During this time he had halter traction and later a plaster was applied, which he wore until November. He was

* Referred by Dr. F. H. Mackay.

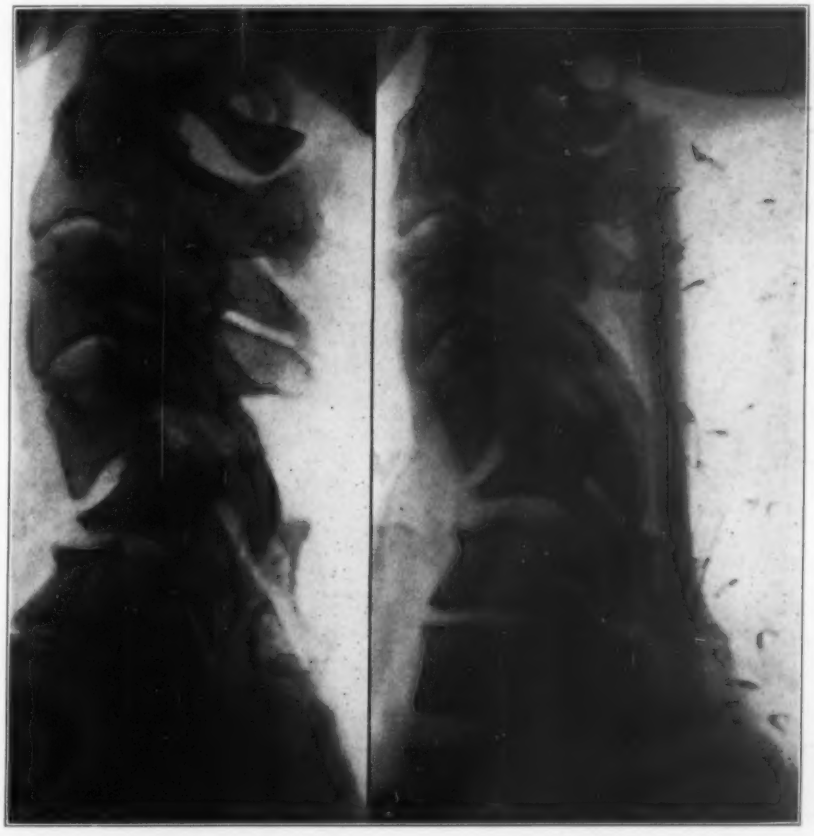

FIG. 5-A FIG. 5-B

Case 4. Relapsed fracture-dislocation of the fourth on the fifth cervical vertebra.

Fig. 5-A: The deformity found nine months after the injury. The relapse had occurred while the patient was still in the cast.

Fig. 5-B: Lateral film after decompressive laminectomy and fusion.

FIG. 6-A

FIG. 6-B

FIG. 6-C

Case 5. Old fracture-dislocation of the fourth cervical vertebra on the fifth.

Fig. 6-A: The deformity present at the time of admission. Although the reproduction of this film does not show it, there was a bony bridge extending from the anterior and inferior part of the body of the dislocated fourth to the body of the fifth.

Fig. 6-B: The bony fusion has been broken by heavy skeletal traction.

Fig. 6-C: This film shows the eventual reduction obtained on the operating table and the bone grafts.

admitted to this hospital on November 12, 1935. He was extremely anxious because the power which he had regained in the hands after the accident was diminishing and he could not carry on any longer as a technician in charge of a serological laboratory.

The roentgenograms showed a fracture-dislocation of the fourth cervical vertebra on the fifth and a compression fracture of the body of the fifth cervical vertebra and bony fusion of the deformity. Although the lumbar manometric test showed no definite subarachnoid block, the total proteins in the cerebrospinal fluid were 65.8 milligrams per 100 cubic centimeters.

Because of the disability of the hand and the weakness of the legs, operation was advised. Heavy skull traction broke the fusion of the bodies anteriorly, but the fusion of the articular facets was too firm to permit any change in the deformity. On November 15, 1935, on the operating table about thirty pounds of traction was maintained. The vertebrae were then exposed and the laminae of the fourth and fifth cervical vertebrae were removed. There was no change in the deformity until the facets between the fourth and fifth vertebrae were rongeured away and, as the last portions were removed, reduction and realignment slowly took place without manipulation. Parallel rib grafts were then firmly bound with fine rustless-steel wire to the laminae of the second, third, sixth, and seventh cervical vertebrae. The articular cartilages of the facets not already removed were curetted away.

The patient's postoperative course was smooth and the neurological condition improved steadily. As soon as possible a modified Minerva plaster was applied and the wire traction was removed. This support was continued for six months. At the end of this period, the patient had completely recovered and resumed his work with some limitation of neck movements but with no discomfort. One year later, solid fusion of the bone graft was demonstrated by x-ray.

In this case, the laminae of the fourth and fifth cervical vertebrae were removed, so that the grafts had good contact with only the second, third, sixth, and seventh cervical vertebrae. Yet, one year later, the bony bridge showed solid fusion and some increase in size of the grafts. If we had carried out the same procedure in Case 4, unlocking the fused facets, it is possible that this patient's deformities might also have been reduced.

CASE 6. *Fracture-Dislocation of the Sixth Cervical Vertebra on the Seventh with Marked Instability.* (See Figures 7-A, 7-B, and 7-C.)

G. M., aged forty-seven, was referred on May 12, 1936, by Dr. Warren Lynch, of Sherbrooke, Quebec. Seven days prior to coming under our supervision, the patient had fallen from a roof onto her head, producing a fracture-dislocation of the sixth on the seventh cervical vertebra. She was conscious and able to crawl to the house to await assistance. The first treatment was continuous traction with a neck halter. Partial reduction was obtained, but pressure sores developed on the chin and over the occiput and, when traction was removed, the deformity recurred. Four days after the injury, skeletal traction was applied to the skull with rustless-steel wire sutures, and a frame was improvised, so that traction could be maintained during transportation by ambulance from Sherbrooke to Montreal.

Upon her arrival at this hospital, the usual apparatus for skeletal traction was used and an operation was carried out with skeletal traction still immobilizing the neck. The cervical and upper thoracic vertebrae were exposed. The comminuted facets of the sixth and seventh cervical vertebrae were removed and the fractured laminae and spine of the sixth cervical vertebra were lifted away. The sharp bone fragments had lacerated the dura, so that cerebrospinal fluid had percolated into the neck muscles and poured out, filling the field during the procedure. The dura was not opened because pulsations were free and there was no evidence of block. Bone grafts were removed from the tibia and fixed in contact with the laminae by rustless-steel wire sutures passed through drill holes in the base of the spinous processes. The fusion included the third, fourth, fifth, sixth,

FIG. 7-A

FIG. 7-B

FIG. 7-C

Case 6. Fracture-dislocation of the sixth cervical vertebra on the seventh with marked instability.

Fig. 7-A: The initial deformity (films taken by Dr. Warren Lynch of Sherbrooke).

Fig. 7-B: The reduction obtained by traction.

Fig. 7-C: Lateral film after laminectomy and fusion.

and seventh cervical vertebrae and the first and second thoracic vertebrae. Postoperative roentgenograms showed that reduction was maintained. The wounds healed perfectly, despite an attack of pyelitis, and, on June 3, 1936, plaster fixation was applied and skeletal traction was then removed. The patient was discharged from the hospital on June 28, 1936, walking.

She steadily gained strength and when she returned for follow-up examination, five months later, the only objective abnormal neurological findings were hyperactive deep reflexes throughout, more ready fatigability of the right abdominal reflexes, slight diminution of temperature sensation over the left foot, and unusual sweating of the hands and particularly of the feet. The vertebral alignment was excellent. The bone grafts seemed to have slightly increased in size and appeared to be fusing well.

It is surprising that the spinal cord escaped with so little damage. The deformity was extreme and the comminution extensive, and tiny sharp bony fragments had torn the dura and opened the arachnoid.

Although fair reduction was obtained by traction, the extensive comminution and instability necessitated complete exposure, accurate reduction under direct vision, and fusion; otherwise, added damage to the spinal cord would surely have occurred.

DISCUSSION

We have presented the case histories of six of the twelve patients whom we have treated by bone grafting, and these cases illustrate our indications for fusion. Of the other six patients, three were referred after late deformities had developed and spinal-cord involvement was advancing. In these three cases the operations were considered operations of necessity and not of election. Two patients had atlanto-axial dislocation with fracture of the odontoid process. In the twelfth case, although roentgenographic evidence was lacking, because of the neurological findings, we assumed that the patient had suffered an atlanto-axial dislocation which had spontaneously reduced. Respiratory movements would cease when this patient was shifted and we did not dare to attempt roentgenographic studies in the positions in which the dislocations recurred. Operation was done with the neck immobilized by skeletal traction on the operating table. The exposure was carried out under local anaesthesia, the bone graft being removed from the tibia without any anaesthesia because sensory loss was complete. This patient is walking and has some use of the hands. The diagnosis at discharge was upper cervical hematomyelia, due to atlanto-axial dislocation. The paralysis of the neck muscles, due to a lesion of the anterior-horn cells, was one of the indications for fusion. In spite of this, the fusion is satisfactory eight months after operation.

We have followed a rather rigid routine in handling and studying the acute injuries after admission to the hospital. Neurological and general physical examinations are just as complete as the patient's condition will permit. In many instances much of the examination has been carried out in the x-ray room in the intervals between x-ray exposure and the development of the films. As a rule, we do not move the patient from the

FIG. 7-A

FIG. 7-B

FIG. 7-C

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FIG. 8

Tongs for skeletal traction designed for us by Dr. Lyman G. Barton, Sr. They are shown in place on the skull of the patient whose cervical x-rays are shown in Figs. 10-A to 10-F.

bed for the roentgenographic studies; lateral films are taken with cassettes held at the side and pushed down into the mattress. Roentgenograms taken through the open mouth and anteroposterior views of the other cervical vertebrae are obtained only when the attending physician is present to immobilize the head manually as the film holders are being placed. The bodies, pedicles, facets, and laminae have usually been well defined and a most valuable anatomical diagnosis has been the result. The roentgenogram of the base of the skull is invaluable for visualization of the anterior arch and the articular facets of the atlas. For this, the patient must be shifted to the x-ray table.

Lumbar manometric tests are then carried out with the same meticulous care. Digital compression of the jugular veins is not used, but, to block the venous return from the head, a blood-pressure cuff is placed around the neck with its manometer attached and then the exact amount of compression is known[4]. If roentgenograms have shown a deformity and a subarachnoid block is present, skeletal traction is applied with the patient in bed. To obtain traction, we use tongs designed for us by Dr. L. G. Barton, Sr. (Fig. 8), or heavy rustless-steel wire through small open-

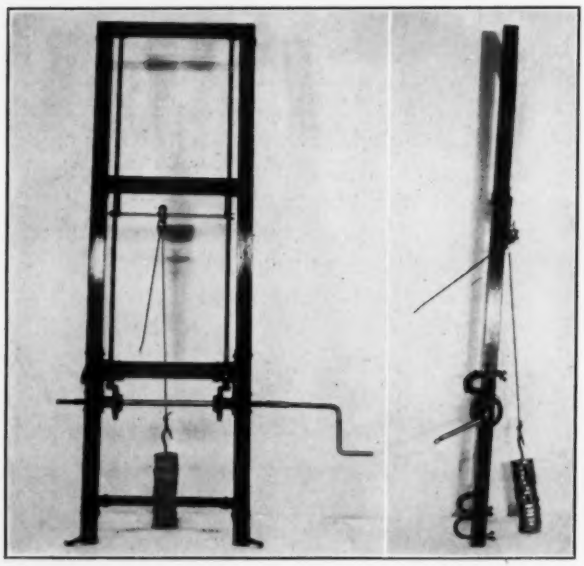

FIG. 9-A FIG. 9-B

Fig. 9-A and Fig. 9-B
Anterior and lateral views of traction frame. Any angle of traction can be obtained and the pulley on the cross-bar moves from side to side, so that, when the patient turns or is shifted to either side of the bed, the traction pulley shifts automatically and simultaneously.

ings in the skull made with a trephine or a Hudson burr. (See Figure 2-D.) The apparatus (Figs. 9-A and 9-B), designed, made, and presented

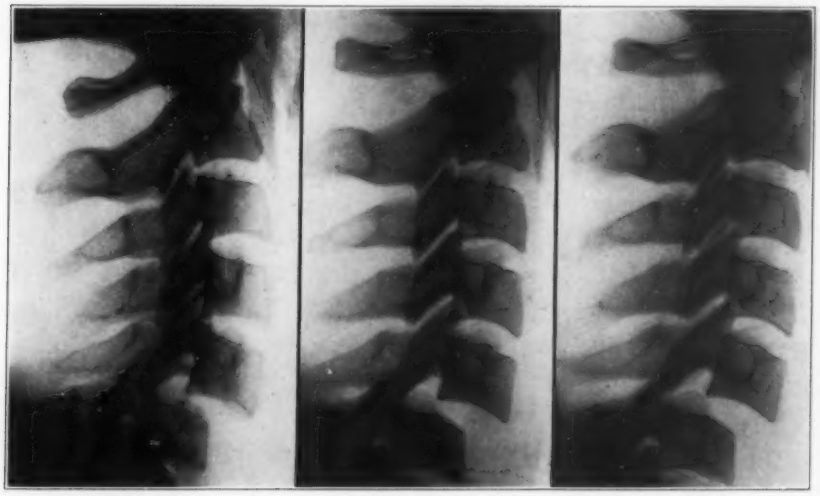

FIG. 10-A FIG. 10-B FIG. 10-C

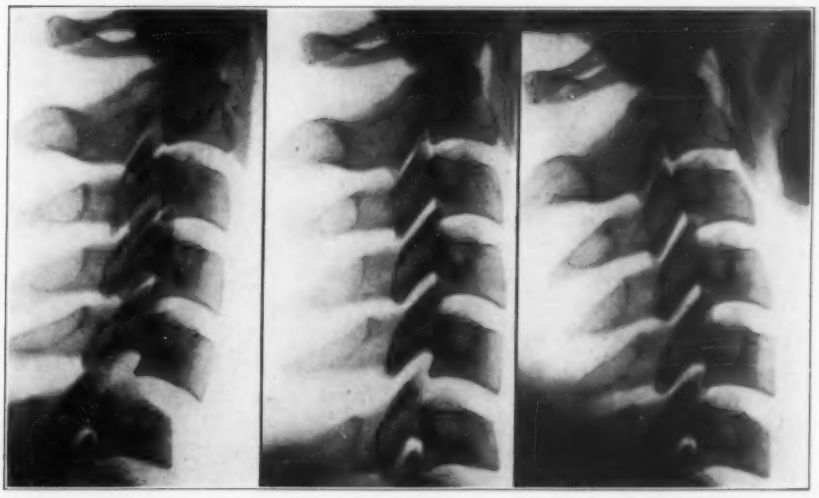

FIG. 10-D FIG. 10-E FIG. 10-F

Fracture-dislocation of the fifth cervical vertebra on the sixth, showing the initial deformity and the various stages of reduction.

Fig. 10-A: Deformity on admission. The articular facets are locked.

Fig. 10-B: After ten minutes of traction.

Fig. 10-C: After twenty minutes of traction.

Fig. 10-D: After thirty minutes of traction. The articular facets have separated and the deformity is less.

Fig. 10-E: The deformity is corrected. The articular facets have been unlocked.

Fig. 10-F: The bed gatch has been elevated and the traction lowered, and the weights have been reduced from twenty-five to eight pounds, allowing hyperextension of the neck and engagement of the articular facets in their normal position.

Before reduction, there was a complete manometric block. Immediately after reduction, the test was repeated and the block was found to have been completely relieved.

to us by Mr. G. H. Duggan, has contributed greatly to the simplicity of reduction and the comfort of the patients. It can be quickly attached to the bed, and the vertical screw arrangement permits the angle of traction to be altered slowly and smoothly. By altering the bed gatch and this angle of traction, reduction is facilitated. Figures 10-A to 10-F inclusive show how reduction is obtained by these two measures without any other manipulation and with but little discomfort. In this case, traction at first was made in the line of the upper cervical vertebrae,—that is, in the line of the deformity, to avoid leverage at the site of the fracture. When the articular facets were disengaged, the gatch was elevated and the traction bar lowered. The progress was followed with roentgenograms every ten minutes and reduction was complete after fifty minutes. Before reduction, there was an absolute manometric block which was found to be relieved when the test was repeated after the last roentgenogram was taken. This case is cited to show the value of this technique of reduction. The facets were not fractured and the bodies were intact. The indications for fusion, we felt, were not present. McKenzie, Crutchfield, and Hoen have shown the value of skeletal traction. Once the traction has reduced the deformity and relieved the block, the safety of the spinal cord is assured as long as the proper angle of traction is continued. The apparatus described has permitted lateral movements of the traction pulley on the cross-bar and allows the patient to be turned safely for back care and dressings. (See Figure 11.)

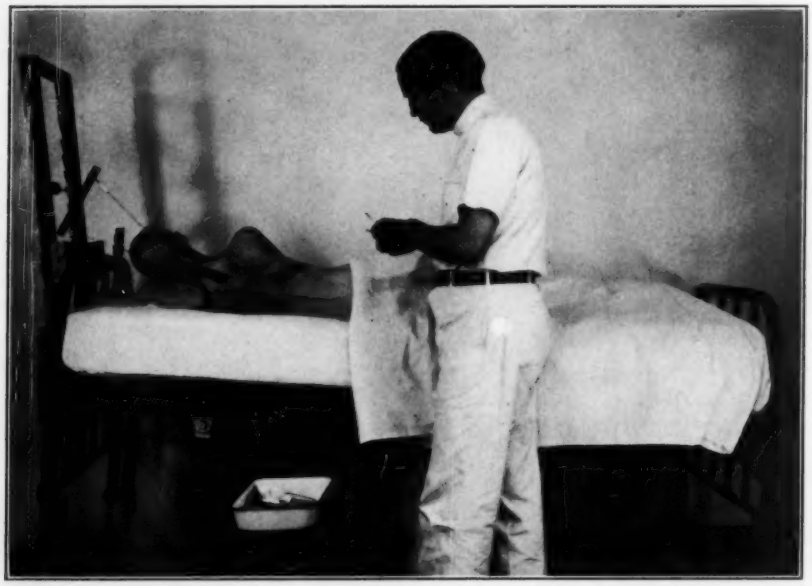

FIG. 11

Skeletal traction simplifies the postoperative care of patients. Turning can be accomplished with very little discomfort and without disturbing the alignment. Dressings are easy and the nursing care is simplified.

This photograph, demonstrating a dressing being done on the patient in Case 2, shows the cervical incisions and the incision over the rib where the graft was obtained.

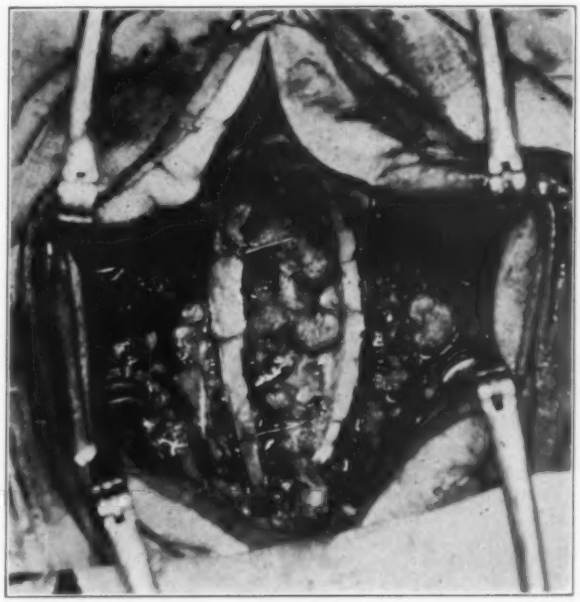

FIG. 12

At operation, showing upper cervical fusion for fracture of the odontoid. The rib has been split and the two halves have been tied against the laminae with rustless-steel wire sutures through drill holes in the spines.

We want to emphasize three points in the surgical technique of the fusions. First, traction is maintained during operation. We have seen reduction take place on the operating table (Case 5) due to the traction alone without any manipulation other than that of rongeuring away bone which had fixed the facets. Secondly, because the exposures must be obtained by the gentlest means possible, we have dissected with the electrosurgical unit, baring the spines, laminae, and articular facets, and have avoided using periosteal elevators as much as possible. This has completely denuded the bone and prepared a bed for the grafts. Hemorrhage is minimal. Thirdly, we have used Babcock's rustless steel to tie the grafts in place and to close the muscles in layers over them. This suture material is easily handled, it is positively sterilized by boiling, and we have found by animal experimentation that there is less tissue reaction about it than with catgut or even with silk. It stays tied.

The bone grafts have been taken either from rib, tibia, or ilium. If a rib is to be used, drapings can be arranged so that but one operative field is prepared and a curve of rib can be chosen which may be better fitted to the spine. Tibial grafts have been satisfactory. The ilium gives flexible ribbon grafts which are readily adaptable in occipital cervical fusions (Case 1) and supplemental grafts can be easily obtained when required.

In all cases we used parallel grafts. (See Figure 12.) Articular facets above and below the lesion have frequently been curetted.

In this series of cases, where grafts have bridged the space of one or two arches without bone contacts at this level, the grafts have nevertheless survived, as noted in cases reexamined from six months to four years after operation, with increase in size of the grafts as shown by the roentgenogram.

As soon as the wound permits, plaster fixation of the head, neck, and torso is applied and the skeletal traction is removed. It is wise to have these patients up as soon as their motor power is adequate and they have

become accustomed to the plaster fixation. The patients are much happier and their general health is better. The plaster immobilization should be maintained for six months.

SUMMARY

Skeletal traction has been proved to be of great value in the reduction and immobilization of fracture-dislocations of the cervical spine, especially when the bed frame with its vertically movable, pulley-carrying cross-bar is used.

From our experience, we have concluded that fusion is indicated when more than one of the bony structures are injured. In fracture of a body alone, fusion is not necessary, but it is advisable in multiple fractures. We feel that when fracture of the odontoid is present, even though there is no other demonstrable vertebral injury, the patient is safer with fusion. When deformities recur after reduction, in spite of careful immobilization, fusion is imperative. Another important indication for fusion in high cervical lesions is paralysis of the neck muscles, due to cell involvement of the anterior horn. We feel that these conclusions are not radical. With fusion, the patient is protected immediately and from late recurrence of the deformity. Fusion not only insures much greater protection, but it allows the natural repair of the damaged vertebra to take place. In the occipitocervical fusions, rotation is lost, but considerable compensatory flexion remains. Below this level, the amount of mobility depends on the extent of the fusion. In this series the patients have resumed their previous activities and have not complained. The follow-up periods range from nine months to four years.

The age of the patients has ranged from six to seventy-two years. There have been no deaths and in none of the cases has there been wound infection. The twelve cases represent our total experience with fusion in the cervical region following trauma.

We wish to express our sincere thanks to Dr. Arthur Childe, radiologist, and to Mr. Walter Whitehouse, radiological technician, for their unfailing interest and cooperation.

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SPINAL DEFORMITY FOLLOWING TETANUS AND ITS RELATION TO JUVENILE KYPHOSIS †*

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INTRODUCTION

The first case of spinal deformity following tetanus was reported in 1907 by Lehndorff. Since Ehrlacher reviewed ten cases and added two of his own in 1921, the number reported in the literature has steadily increased. There may be several reasons for the infrequency of reports of this condition previous to recent years:

1. In young children, especially in infants, kyphosis, or kyphoscoliosis following generalized tetanus, is usually of a transient nature.

2. Lesser grades are observed only through roentgenographic examination of the spine, in which good lateral views are necessary to show changes in contour of the vertebral column as a whole, as well as alterations in the vertebral bodies themselves.

3. The condition is liable to be overlooked in patients, because it is relatively infrequent in adults, the appearance does not always follow immediately on the heels of recovery from tetanus, and moderate degrees are likely to escape observation.

4. The mortality following severe attacks was greater before the introduction of tetanus antitoxin for prophylaxis and treatment; all the cases discussed here received the benefit of this treatment. Nevertheless, it is highly improbable that tetanus antitoxin diminishes the resistance of the vertebral column to stress.

5. Spinal deformity is seldom observed in fatal cases of tetanus, because the spines are rarely examined; also, with rare exceptions, changes are macroscopically invisible, although microscopic changes may be present which probably would have led later to a curvature under the burden of an upright posture.

6. Attention in recent years has been attracted more to the spinal column and to the changes produced in it by tetanus.

Although more frequent than suspected, the condition under discussion is nevertheless not often observed, even though follow-up examinations of tetanus patients from this viewpoint by Friedrich, Chasin, and Zukschwerdt and Axtmann showed varying degrees of kyphosis in thirty of the fifty-four patients whom they examined. However, such a method of examination has the disadvantage of not determining a definite causal and temporal relationship between the tetanus and the vertebral deformity.

The description of post-tetanic spinal deformity which follows is

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based on sixty-three cases, comprising almost all those appearing in the literature up to the present, as well as a hitherto unpublished case of Prof. Arnold Wittek's. The chief features of this deformity will be described and then compared with similar changes in the vertebral column which result from other causes; from these considerations, an attempt will be made to explain why kyphosis or gibbus formation follows some cases of tetanus and not others.

FIG. 1

Case 1. Lateral roentgenogram showing kyphosis in a fourteen-year-old boy, one month following recovery from tetanus.

CASE PRESENTATION

CASE 1.* A boy, fourteen years of age, had had tetanus of three weeks' duration with opisthotonus and convulsions. Figure 1, a roentgenogram taken a month following his recovery, shows a pronounced anterior curvature, extending from the third thoracic to the eighth thoracic vertebra, with extreme flattening and sclerosis of the fourth and fifth thoracic vertebrae and indentation of the anterior surfaces. In the bodies of the fourth to tenth thoracic vertebrae, there is a curved indentation of the articular surfaces, chiefly of the upper surfaces, and, with the exception of the ninth and tenth thoracic vertebrae, in the posterior third of these surfaces. In some of the depressed regions, there is also a moderate sclerosis beneath the cartilaginous end plates. No treatment was instituted and an examination of the boy three months later showed a striking regression of the deformity with good mobility of the affected portion of the spine. Although the roentgenogram made at this time (Fig. 2) does not demonstrate all the vertebral bodies most affected, it does show an increase in height of the vertebrae involved in the kyphos, as well as a haziness and raggedness in outline of the lower thoracic vertebrae.

CASE 2.** The patient was a boy, twelve years old, in whom kyphosis was first noticed immediately following an attack of tetanus. The roentgenogram (Fig. 3) taken six weeks after recovery from tetanus shows an abnormal anterior curvature of the thoracic spine from the fourth to the eighth vertebrae, with a marked anterior wedging of the fifth, sixth, and seventh vertebrae, in addition to sclerosis of the bodies and a haziness of outline. Slight anterior indentation is present here; this indentation results from

* This case has not been previously recorded.

** For permission to publish the roentgenograms of this case the author is indebted to Assistant Dr. Gerhard Haberler of Prof. Haas's *Universitäts-Ambulatorium für orthopädische Chirurgie* in Vienna. This case has also been presented by Gold [24].

the anterior displacement of the upper and lower portions of the body in compression fracture and may be exaggerated by the relative persistence of the infantile central cone defect of the vertebral body (Fig. 3, *T 9*). Also in the ninth thoracic vertebra, the crucial vertebra of juvenile kyphosis, is seen a localized anterior indentation as well as sclerosis of the upper end plate. The roentgenogram (Fig. 4) taken five years later, when the patient was seventeen years old, exhibits a striking reduction in the degree of the kyphosis. The sixth thoracic vertebra, most affected in the first roentgenogram, shows less recovery of height than the others; its upper and lower borders are thickened and wavy, as are those of most of the others shown in this film. In the roentgenogram taken five years later, however, there is not only a regression of the original curvature, but a new arc-like curvature in the lower thoracic spine, best observed by following the outline formed by the posterior surfaces of the seventh to the eleventh thoracic vertebrae. The upper and lower surfaces of the ninth, tenth, and eleventh thoracic vertebrae show sclerosed indentation in the centers, irregular excavation, and hazy, undulating contour. This is a typical picture of a late stage of juvenile or adolescent kyphosis, first emphasized as a clinical entity by Scheuermann in 1921. It is noteworthy that the brother of this patient, aged twenty-nine, exhibited the kyphos shown in Figure 5. One is inclined to attribute this to an adolescent kyphosis and to be reminded of the frequent familial incidence of this condition.

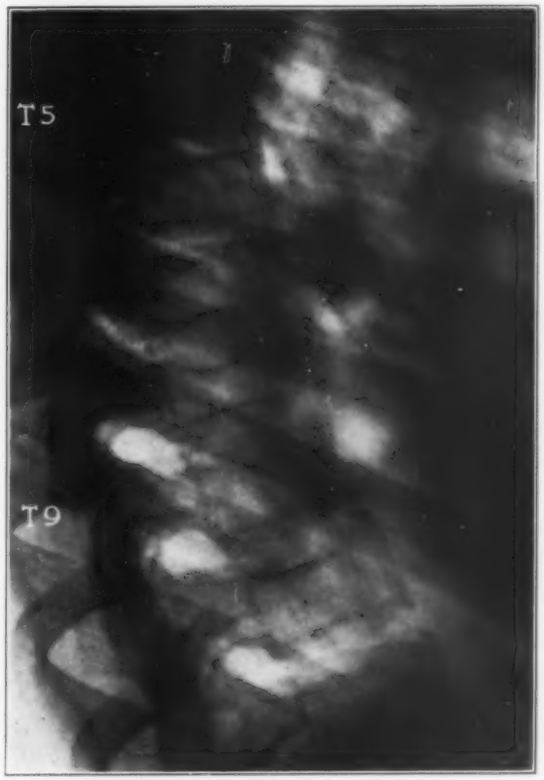

FIG. 2

Case 1. Three months later than Fig. 1.

CASE 3.* The patient, a boy of fourteen, noticed a continually increasing pigeon breast during the third week of convalescence from an attack of tetanus; this attack had lasted two weeks and was marked by opisthotonus and convulsions. Examination showed that a kyphos had developed subsequent to recovery. Prof. Leb's report of the first roentgenogram, taken six weeks after recovery, is as follows: "Fifth thoracic compressed to less than one-half of normal height; seventh and eighth thoracic, to two-thirds. Upper end plate of eighth thoracic indented. Epiphyses show a normally preserved bone nucleus. As a result of narrowing of the anterior vertebral borders and compression fractures of the middle thoracic vertebrae, a thoracic kyphos has been produced." The patient was suspended by the hands and a head sling, with the lower extremities resting on a horizontal support, and, after hanging twenty minutes in this position, he was placed

* This case was previously published by Kamniker merely from the standpoint of treatment.

FIG. 3

Case 2. Lateral roentgenogram showing kyphosis in a twelve-year-old boy, six weeks following recovery from tetanus.

in a plaster corset, which was renewed twice by the same procedure during the next six months. Two months after the first roentgenogram, the one shown in Figure 6 was taken, and Prof. Leb reported: "Slight flattening of fifth thoracic; marked wedge formation of sixth to eighth thoracic, with a diminution in the height of these vertebrae. The upper articular cortex of ninth thoracic somewhat indented (beginning cartilage-node formation). Intervertebral spaces of normal height. Marginal epiphyses normally formed and applied. Moderate kyphosis of middle and lower thoracic spine." A

control picture, taken two months later, bears the following note: "The individual vertebral bodies are sharply outlined and only in the anterior parts of the fractured vertebrae is there an irregular outline with disturbed development of the marginal epiphyses." Here again there is the same irregularity of contour with a slight shifting of the original curvature from the middle or upper portion to the lower portion of the thoracic spine during a later stage of the deformity, in spite of corrective treatment. It is noteworthy that changes in the marginal epiphyses appeared only in roentgenograms taken five and one-half months following recovery from tetanus and four months after a roentgenogram showing them to be normal in spite of marked deformity of the vertebral bodies. Although all films were not available, Prof. Leb, the roentgenologist, informed the author that the roentgenograms of this spine, taken during the following two years, were typical of juvenile kyphosis.

FIG. 4

Case 2. Five years later than Fig. 3, when the patient was seventeen.

CASE REVIEW *

For the purpose of analysis, the number of cases becomes limited in one respect or another, because complete data are given in only a few reports, and even these do not answer all the questions one might ask. Thus the number of cases supplying statistics for one feature will differ from the number of those allowing adequate inspection of another feature. The individual case histories will not be repeated here, and tabulated statistics will be omitted in favor of graphs and of significant figures, with conclusions derived from them.

Nature of the Spinal Curvature

Out of sixty-three cases, a transient kyphosis of the thoracic vertebral column, present only during tetanic convulsions, was noticed in two

* Three cases were added following completion of this paper,—those reported by Randerath, Nagy, and Philippsberg. These are included in the statistical descriptions, but they are not represented in the graphs, although they support the conclusions derived from the graphs.

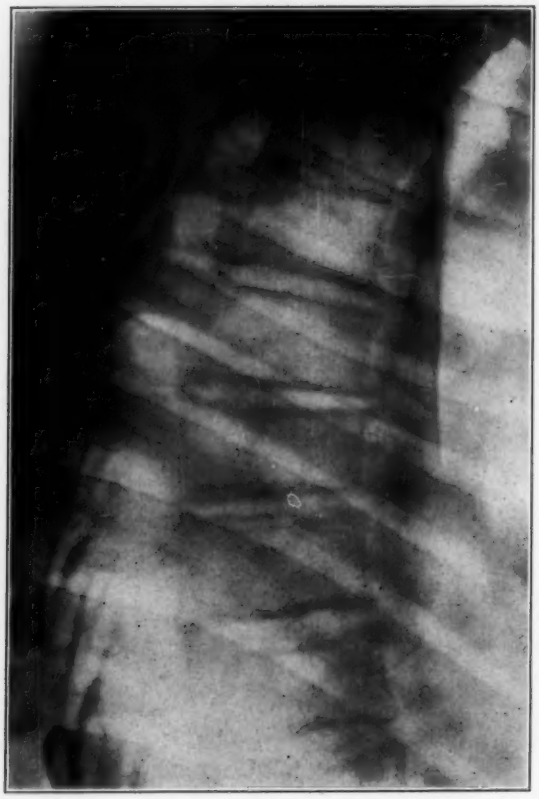

FIG. 5

Kyphotic spine of older brother of patient in Case 2.

infants and in one eight-year-old child. In five other cases, a fracture was regarded as probable in two, and as certain in three (but only from clinical examination). A fracture of one or two vertebral bodies was found at autopsy in four fatal cases of tetanus. Nine others were diagnosed roentgenographically, and two of these were associated with a pigeon breast, or pectus carinatum, which had developed during the convulsions. There were forty-two cases of kyphosis without definite fracture, fixed more or less in proportion to its degree, all with a compensatory lumbar lordosis; in eight of these there was an associated pigeon breast.

Level and Extent of Kyphosis or Fracture

Among thirty cases of kyphosis in which level and extent were described, the peak was recorded in twenty at the sixth thoracic vertebra, and in ten at the fifth thoracic vertebra. The extent varied from two or three thoracic vertebrae to five. In Figure 7, the number of times each vertebral body was affected in thirty cases of post-tetanic kyphosis is indicated by the unbroken line (Curve *1*), and in ten cases of fracture, by the dotted line (Curve *2*).

Distribution According to Age

Of the forty-five cases in which suitable data were given, thirty-two were cases of kyphosis without fracture, and thirteen were cases of fracture. Figure 8 is based on forty-one cases and shows that twenty-six cases occurred between the ages of nine and seventeen; then there was a sharp break in age frequency, and twelve cases were scattered between the ages of twenty and thirty-four. The relative incidence of fracture is seen to be twice as great in the adult group as in the group of younger or adolescent individuals. The cases not included in Figure 8 also contribute to the conclusions derived from this graph.

Sex

The proportion of male to female was thirty-two to ten, and in no case was a girl over seventeen years affected. The adult group was composed exclusively of men.

Symptoms Connected with the Deformity

There was usually some radiating back pain and tenderness over the affected vertebrae, rarely lasting more than a few weeks following recovery from tetanus. The movements of the back as a whole were free and painless when not limited by a residual tetanic rigidity of the muscles, and when the extent of the fixed kyphosis was not great.

FIG. 6

Case 3. Kyphosis in a fourteen-year-old boy, three months after recovery from tetanus.

Physical Background

Although in one case[72] there was a family history of tuberculosis, as well as a clinical suspicion of pulmonary disease with a pathologically proved caries of a finger bone, and although the two cases of fracture of the lumbar vertebrae were associated with gun-shot trauma and suppuration in the affected region, there was nothing in the other cases to suggest a background of disease or defect in the muscular system or skeleton, although most authors have sought diligently for such a background. Brunzel stated that tetanus produces spinal deformity chiefly in rachitic individuals, but there is no case evidence to support this; nor is there evidence that kyphosis preceded the attacks of tetanus in the cases recorded.

Type and Duration of Tetanus

In the younger patients, the time of incubation varied from five days to two weeks, and the average duration of the illness itself was three weeks; this does not include the exceptional case reported by Leube, in which intermittent attacks of rigidity and convulsions occurred over a

period of thirteen months, and where a kyphos with pigeon breast developed in the sixth month. Information on this point was given in eight of the twelve older cases. In six of these, the tetanus had an incubation period of from one to four months and the duration of the attack which, as in all cases, was accompanied by severe convulsions, was from one to three months. In all eight cases, the average period of incubation was seven weeks, and the average duration of the disease was six weeks. In several adult cases, in which the latent form of the disease occurred, a residual tetanic rigidity was noted to be present in the back muscles for some time following recovery. From a further comparison of the two age groups, it is seen that the tetanus required to bend or to break an adult spine had a duration approximately three times as great as that which produced similar changes in younger individuals.

Time Required for the Appearance of the Deformity

This figure is naturally subject to variations in accuracy of observation and in the time intervals of follow-up examination. The development of a kyphos or a gibbus was noticed in practically all of the younger group either during the attacks or immediately following recovery from them. In two of the eight adults for whom data are available on this point, spinal curvature was noticed at the time of recovery; in two others, six weeks later, and in four others, after one, one and one-half, two, and three years, respectively. It is apparent that the development of a kyphos or a gibbus requires a longer period of time in the adult group than in the younger group. One might like to observe that kyphosis immediately following tetanic convulsions in an adult should be produced by the fracture of a relatively brittle vertebral body, and that kyphosis of late development should be the result of the gradual bending of the spine after an initial injury over a greater period of time. Although the adult vertebral column has attained ossification and is more stable and brittle than the adolescent spine, and although it will later be shown that differences of this sort are fundamentally responsible for the division which has been made between adult and juvenile spinal deformities, an examination of the material fails to show that a fracture necessarily appears early and that a uniform kyphosis appears late. Furthermore, although we see kyphosis appearing in a few cases only after the lapse of months, we may not assume that a residual tetanic contraction of the musculature continues to act to produce this deformity, because, as will be pointed out later, the rigidity of those muscles which produce an increase in the normal thoracic anterior concavity would hardly escape clinical observation. Even though it is apparent that tetanus of longer duration and greater severity is necessary to produce anatomical alteration in the vertebral column of an adult than in that of a younger individual, we must assume that the initial damage to the spine ends with the recovery from tetanus, and that later changes are due to secondary processes in the vertebral bodies which are exposed to

the function of supporting the body in its carriage and muscular movements.

Four striking examples of such secondary changes may be cited. Chasin [12] described the case of an intelligent doctor, twenty-six years old, who developed trismus and convulsions nine days after an injury to his elbow. These lasted twenty-two days and the patient stated that during a convulsion he heard and felt a sharp crack in his back. At the time of discharge no deformity was observed. A year later the patient again entered the hospital because of a postscarlatinal nephritis, and a moderate kyphosis was observed in the upper thoracic spine. Roentgenographic examination showed a confluent destruction of the fifth, sixth, and seventh thoracic vertebrae without paravertebral abscess or other evidence of tuberculosis; of the fifth thoracic vertebra there were only splintered traces. Zukschwerdt and Axtmann described a case in which the spinal column was roentgenographically normal following an attack of

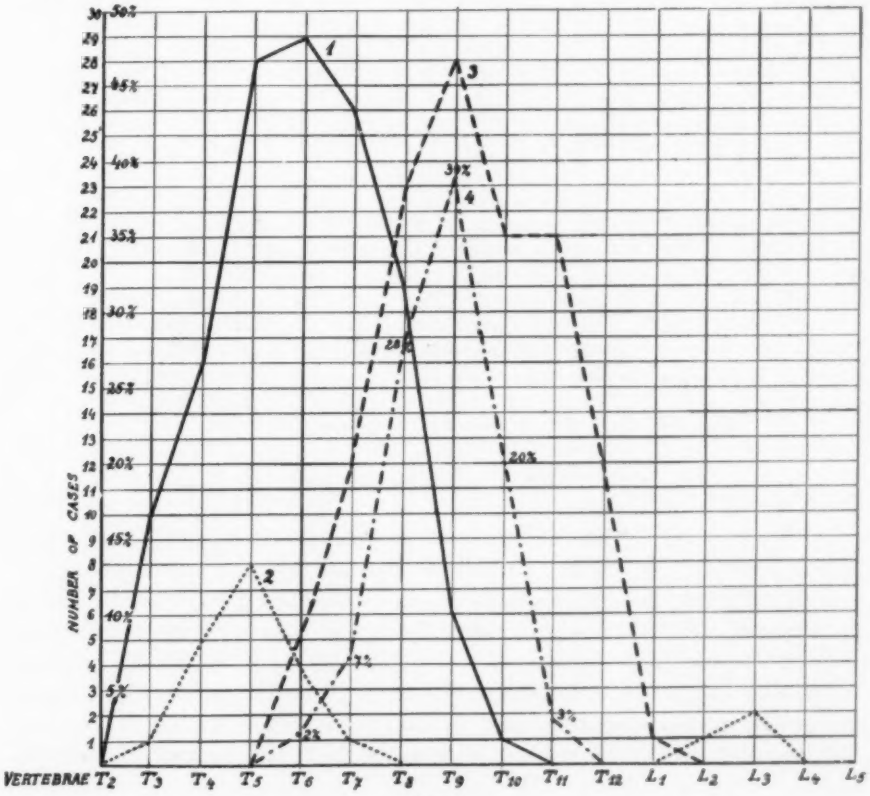

FIG. 7

Relative incidence of affected vertebrae.

Unbroken line (*1*) = Thirty cases of post-tetanic kyphosis.
Dotted line (*2*) = Ten cases of post-tetanic fracture.
Interrupted line (*3*) = Thirty cases of juvenile kyphosis.
Dotted and broken line (*4*) = Percentage incidence of vertebrae forming the apex of the normal thoracic curvature.

tetanus. Six months later, a collapse of three vertebral bodies was found. In another case, three bodies were seen to be compressed one year following recovery. A subsequent roentgenogram, taken three months later, showed a flattening of two more vertebrae. A fourth case, that of a ten-year-old boy, revealed a high-grade compression of three vertebral bodies six months following recovery; six months later the number had increased to five or six.

Nature of the Changes in the Vertebral Bodies Themselves

A good description of these is found in twenty-two cases of kyphosis and in ten cases of fracture. In four fatal cases of tetanus, fresh fractures of vertebral bodies were demonstrated anatomically; apart from mechanical disturbance of structure, the vertebrae were normal. We shall return to a detailed consideration of these later. On

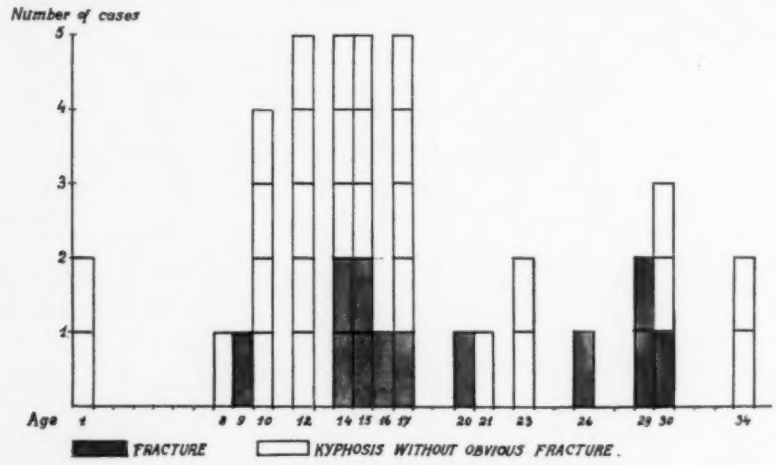

FIG. 8

Age incidence of patients with post-tetanic spinal deformity.

the other hand, the roentgenographic determination of a fracture is less certain. A fragmentation of the bony structure extending through the periphery of the shadow is certain evidence of fracture. A displacement of one portion of the body against another part in a sagittal or frontal direction also demonstrates a fracture. Flattening in a vertical direction or isolated wedge formation associated with a continuous line of increased density in the interior of the body, even in the presence of an intact outline, is suggestive of a break in the spongiosa. In cases of kyphosis in many young individuals [30], the indentation of the anterior surface in the compressed bodies may be regarded more as evidence of a predisposition to rather than as a result of fracture. Another criterion is the formation of a sharp angle at the junction of two lines which are drawn through the longitudinal axes of successive vertebral bodies in a lateral view of the spine; this, however, can apply only to a sharp break in contour. The

usual kyphoses, such as the postural and senile types, are of gradual development and do not give occasion for the determination of whether or not a microscopic fracture may play a part. In the kyphoses of rickets, tuberculosis, multiple myeloma, tumor metastases, Paget's disease, ostitis fibrosa generalisata, etc., if fracture occurs there is an evident pathological basis. However, it is far more difficult for the roentgenologist than for the pathologist to separate a true fracture, associated with a single collapse and shattering of the bone trabeculae and hemorrhages, from a change in form of the vertebral body, associated with a mere gradual transformation of the bone tissue. Where a very evident fracture of the spine occurs, the action of the force is of such short duration that, unless a fracture occurs at the time, the vertebral column usually escapes without injury; however, such trauma can sometimes lead to progressive disintegration of the cancellous bone, as in Kümmell's disease, or to progressive vertebral atrophy. It is one of the striking characteristics of the spinal deformities following tetanus that a field is offered where kyphosis and fracture result from the same cause, and that the border-line between a bend and a break in the vertebral column is here far more transitional than in the other conditions just mentioned. There is little doubt that fractures of slight degree in adjacent vertebral bodies can produce simply a uniform exaggeration of the normal anterior curvature of the thoracic vertebral column.

To turn to the roentgenographic reports of twenty-nine cases: of the twenty-two cases diagnosed simply as kyphosis, a wedging or flattening of the involved bodies was described in all except four; these four comprised cases in which the patients were between the ages of twenty-three and twenty-eight, in which the time interval following tetanus was not given, and in which a roentgenographic kyphosis existed without change in the shape of the vertebral bodies and without diminution in height of the intervertebral spaces. In sixteen cases, there was an abnormal indentation of the upper or lower end plates, usually not pointed out by the authors, but observable in the roentgenograms especially of the spines of younger individuals, where the superior and inferior contours are normally either straight or only slightly convex. In six of these there was a line of marked sclerosis or condensation of the spongiosa just beneath the end plate. In four cases, there was a notching of the anterior surfaces of the affected bodies; the ages of these four patients were ten, ten, twelve, and fourteen years, respectively. Of the cases of fracture, apart from those determined at autopsy, one showed a chipping-off of the anterior superior corners of the seventh, eighth, and ninth thoracic vertebrae to an extent and clarity that exclude confusion with delayed or absent union of the ossifying cartilaginous epiphysis. Three others of this group of roentgenographically diagnosed fractures gave a flattening and fragmentation of one or more vertebral bodies,—two showed an acute wedge formation of two adjacent bodies, in one of which there was an obliteration, and in another a narrowing of the intervertebral space; and one

showed a wedge formation with indentation of the end plates. A further case showed clinically a sharp gibbus with its crest at the level of the third lumbar vertebra. In a number of cases of both kyphosis and fracture, there was some atrophy of the affected vertebrae.

Subsequent Course of the Vertebral Deformity

Friedrich examined three cases of acute kyphosis following tetanus incurred during the War, in which examination was made eleven, seven, and five years, respectively, after the primary illness. The patients were probably adult at the time of the onset of tetanus, although the ages were not given. Zukschwerdt and Axtmann described four individuals between the ages of twenty-three and twenty-eight, showing moderate kyphosis in the region of the fourth to the ninth thoracic vertebrae, who at one time or another (not recorded) had had tetanus. Neither the age at which the tetanus occurred nor the time elapsing after recovery from it was given. Such reports indicate only that the curvature was probably the result of the tetanus and that later it did not entirely disappear. Becher's case of post-tetanic kyphosis, occurring in a man, twenty-three years of age, was examined two years later by Spieth, who found no improvement in deformity at that time. Another case of a man of the same age showed little improvement at a later date. Kyphosis in a sixteen-year-old youth disappeared a month following recovery from tetanus. A twelve-year-old girl, a patient of Ehrlacher's [17], exhibited no improvement in the kyphosis, although Ehrlacher succeeded in obtaining complete reduction of a kyphos, involving the third to the ninth thoracic vertebrae in a ten-year-old boy, by means of successive bracing of a Calot reduction cast with felt pads. A case already mentioned is that of a boy of ten years who had a marked kyphos, with flattening, wedging, indentation, and sclerosis of the bodies of five thoracic vertebrae one year after recovery. Because of radiating back pain for weeks following the attack of tetanus, the patient wore a plaster jacket for six months. Five years later, the kyphos had entirely disappeared, and a lateral roentgenogram at that time showed an almost complete return of height of the affected vertebrae, although irregularities in the upper and lower surfaces, sclerosis, and spotted and streaked areas of increased density were still present. An increase of deformity during the first year limits the possibility of benefit from the plaster jacket. The nine-year-old girl with fractures of the second and third lumbar vertebrae retained the gibbus three years later, as well as a hyperreflexia of one leg. Two cases of tetanus neonatorum were described in which the convulsions produced a kyphoscoliotic distortion of the spine which disappeared after the convulsions. Bakay recorded a similar occurrence in a child of eight years.

In no roentgenograms of an adult case of post-tetanic kyphosis has the author been able to find a haziness of the upper and lower margins of the vertebral bodies with an undulating irregularity and spotty sclerosis in these areas; in adults, the changes are more linear and sharply

outlined. The greatest inequality in central translucency and opacity is also found in the cases of younger patients.

SUMMARY OF FEATURES OF POST-TETANIC SPINAL DEFORMITY

1. Spinal deformity following tetanus assumes the form, in most cases, of a uniformly curved, often rigid kyphos in the upper or middle thoracic vertebral column; in a limited number of cases a fracture was demonstrated pathologically or roentgenographically at this level, and in two cases there was a compression fracture in the lumbar region.

2. Twenty-six cases of anatomical deformity occurred between the ages of nine and seventeen, of which seven were cases of fracture; only twelve of the cases occurred in adults, approximately one-half of which were cases of definite fracture.

3. In each case, the patient's physique was almost without exception that of an otherwise normal, healthy individual.

4. In the adolescent group, the attack of tetanus was of about three weeks' duration, and the incubation period was from five days to two weeks; whereas the adult group was characterized by a latent tetanus with an average incubation period of seven weeks for all cases, and a duration of the tetanus itself of six weeks.

5. In most of the adult cases, the deformity was noticed only after the lapse of a long period of time.

6. The changes in the vertebral bodies themselves consisted of flattening and wedging of the affected vertebrae, with a particular blurring, thickening, and indentation of the superior and inferior surfaces in the younger patients.

7. The cases of post-tetanic kyphosis showed a marked tendency toward regression of the deformity in younger individuals, and in the three cases, the roentgenograms of which are presented, this regression was accompanied by a slight increase in thoracic curvature below the original deformity, with changes in outline further characteristic of juvenile kyphosis.

From this survey, one gains the impression that the adult spine is more resistant to tetanus and less plastic than the adolescent spine; also, that if regressive changes do take place in adults, they are not accompanied by the same changes in the end-plate region seen in the incompletely developed vertebral column of adolescent individuals.

THE MECHANISM OF THE SPINAL DEFORMITY

Distinctive Location of the Curvature

The spinal deformity following tetanus is typically a gibbus or a kyphos in the upper thoracic spine, affecting chiefly from four to five vertebrae, with a well-defined crest usually at the level of the sixth thoracic vertebra (Fig. 7). In many respects, it is comparable to a traumatic gibbus or to kyphosis dorsalis adolescentium,—in extent, in

degree, and in the time required for development, as well as in the structural alterations seen in the roentgenograms of the vertebral bodies. Schmorl and Junghanns (page 140) [68] mention the fact that a traumatic kyphosis is often difficult to distinguish from juvenile kyphosis in a roentgenogram. Where fracture has taken place, one sees fragments and depressions most often on the upper edges of the anterior surfaces of the bodies, as in the common compression fractures of the spine [25, 59, 60]. However, the level of fracture is different from that seen in traumatic vertebral compression. From five different statistical tables [25, 68] the following order of frequency is derived from vertebral bodies affected by a compression fracture: (1) twelfth thoracic; (2) first lumbar; (3) sixth cervical; (4) fifth cervical; (5) seventh cervical and second lumbar; (6) eleventh thoracic; (7) third lumbar; (8) fourth lumbar; (9) tenth thoracic; (10) fourth cervical and sixth thoracic. In the usual compression fractures of the spine, the mobile junctures of the three main portions are chiefly affected, in sharp contrast to the middle portion of the thoracic spine, which is broken or bent in almost every case of post-tetanic spinal deformity. Nor does the level in the case of tetanus correspond to an exaggeration of the normal, statically conditioned thoracic curvature. Figure 7, Curve *4*, showing the relative frequency of the apical vertebra in the normal thoracic spine, gives a curve lower than that of the tetanus curvature, but corresponding exactly to the level of that in juvenile kyphosis (Curve *3*).

Tetanic Convulsion

Muscle contractions and convulsions in tetanus may have only a local extent; they may be unilateral, or they may produce an acute anteflexion of the trunk, but these are exceptions. Tetanus which produces spinal deformity is generally of the "opisthotonus" type, with bilateral tonic and clonic contractions of the trunk muscles from neck to hips. The neck is retracted, the buttocks are drawn backward on the spine, and there is convulsive fixation of the thorax in the expiratory position, often with a transient depression on both sides of the sternum. A rigidity of the abdominal muscles may be the first to appear. The neck muscles stand out and the pectorals and the latissimi dorsi are contracted. The presence of an exaggerated lumbar lordosis is emphasized by unsuccessful attempts to make a lumbar puncture during the acute stage [1, 4, 42]. A retraction of the neck with lordosis of the cervical spine is evident and causes clinicians to speak of opisthotonus and to question that a thoracic kyphosis could result from it. Ehrlacher and Bakay have both seen transient convulsive kyphosis and kyphoscoliosis in infantile tetanus. Also from the nature and development of tetanic kyphosis, it is obvious that the typical tetanic convulsion bends the thoracic spine anteriorly. A slight scoliotic component is often present.

Rôle of the Spinal Extensors

The opinion that a contraction of the spinal extensors alone could

lead to an increase in the normal thoracic anterior concavity between the cervical and lumbar anterior convexities is contradicted by the fact that normal physiological contraction of the back muscles bends the entire spine backward, and by the fact that the muscular ridges of all spinal extensors lie on the posterior surfaces of the transverse processes. Even where an abnormal thoracic kyphosis is already present, these spinal extensors could not possibly fall into line with an anterior thoracic concavity, but remain always posterior to the longitudinal axis of the vertebral bodies [28]. The only members of the spinal muscles contributing to an anteflexion of the spine are the serrati posteriores, whose superior division runs from the transverse processes of the sixth cervical to the second thoracic vertebrae to the second to the fifth ribs, and whose lower division lies similarly between the transverse processes of the eleventh thoracic to the third lumbar vertebrae and the ninth to the twelfth ribs (Fig. 9, *3* and *4*). Contraction of these muscles favors a thoracic kyphosis. The remaining spinal muscles belong to the erector group (Fig. 9, *13*). In contrast to the great strength of this group in the cervical and lumbar regions is its marked weakness over the thoracic spine. The short muscles of the medial tract, the interspinales, are attached between the spinous processes, but in the thoracic region are insignificant and mostly absent. The attachments of the remaining muscles of this group bridge the greatest gaps between spinous and transverse processes in the thoracic spine; and in this region the ligamentum supraspinale is especially weak. In general, the fourth, fifth, sixth, and seventh thoracic vertebrae, the region of the usual tetanic gibbus or kyphos, are least covered by the spinal erectors and least resistant to a contraction of the anterior trunk musculature.

Rôle of the Spinal Flexors

It has already been stated that certain spinal muscles aid the forward bending of the upper trunk. When one thinks of the round-shouldered boxer, the hunching position of the back in the downward movement of the crawl stroke in swimming, and the convulsive forward bending of the body in coughing, one sees the action of certain muscle chains (Fig. 9) in transmitting the contraction of the anterior body musculature to the vertebral column. Spitzy cited the condition of deficient body constitution in which there are defective posture and increased thoracic kyphosis caused by hyperactivity of the respiratory muscles. Edelstein presented the case of a fourteen-year-old boy, in whom a well-developed adolescent kyphos appeared during a two-month siege of bronchopneumonia. In this case, one can exclude static trauma during the appearance of the curvature, but the flattened vertebrae were the sixth, seventh, and eighth thoracic vertebrae, comparable to the "dynamic" level in tetanus and contrasted with the usual "static" level in juvenile kyphosis. This suggests that coughing during the illness may have provided the contributing mechanical factor.

One of the muscle chains mentioned is formed by the latissimus dorsi and the pectoral muscles (Fig. 9, *7* and *5*), which draw the lower spine and upper thorax together toward a common point on the upper humerus which is fixed in the shoulder joint, and by the trapezius and the deltoid muscles. The upper ribs and spine are drawn together by the second chain (Fig. 9, *6*), which is composed of the serratus anterior, the rhomboidei, and the levator scapulae. The action of this chain is seen in the winged scapula found with the pigeon breast, often associated with post-tetanic spinal deformity. A third chain is seen in the diaphragmatic attachments between the upper lumbar vertebrae and the inner surfaces of the lower ribs and sternum (Fig. 9, *10*); expiratory contraction of the diaphragm draws the lumbar spine and the lower ribs toward each other and can also contribute to the production of a pigeon breast. Three other groups also contribute to this upward bending of the lower spine: (1) the obliquus externus abdominis and the obliquus internus abdominis (Fig. 9, *8*), inserted into the lower ribs and the linea alba and originating from the lumbothoracic ligament, the iliac crest, and the inguinal ligament; (2) the quadratus lumborum (Fig. 9, *11*), attaching the iliac crest and the iliolumbar ligament to the lumbar vertebrae and the lower border of the twelfth rib; and (3) the iliopsoas (Fig. 9, *9*), connecting the lumbar vertebrae with the iliac fossa and the lesser trochanter of the femur. The diaphragm and the last three groups tend to flatten out the lumbar lordosis and even to cause a lumbar kyphosis in the absence of predominating contraction of the spinal extensors and of the flexors of the upper trunk which would cause the spine to give at a higher level. In the two cases [8] in which a tetanic fracture of the second and third lumbar vertebrae occurred, pieces of shot were present in this region, and, in addition to the factors of nephrectomy and suppuration in the younger patient, could have given rise to a particularly severe local tetanus of the muscles just mentioned. Hammer [29] reported a case of tetanus localized in the muscles innervated by the left lumbar plexus.

Not only does the sternum comprise a fixed point anterior to the spine toward which the upper and lower muscle chains can bend the thoracic spine, but the powerful chain of anterior trunk muscles exerts a force of primary importance. This action begins in the sternocleidomastoidei (Fig. 9, *1*), which produce a retraction of the neck when acting simultaneously and when the head has already been tipped backward. These and the scaleni (Fig. 9, *2*) fix the upper end of the sternum and the thoracic cage to the mastoid processes and the cervical spine, and the contracting force becomes transmitted over the thorax through the sternum, and the pectoral, intercostal, subcostal, and transversus thoracis muscles, and the ribs, to the recti abdominis (Fig. 9, *12*), which in turn anchor the chain to the pubic bones and enable it to exert its tremendous leverage on the spine, which is far greater than that of the spinal extensors because of its position far anterior to the vertebral column. This chain operates also through the leverage arm of the ribs, which, according to Braus, exerts a

FIG. 9

Diagrammatic representation of muscle chains acting in tetanus to produce spinal deformity:

1 = sternocleidomastoideus;
2 = scaleni;
3 = serratus posterior superior;
4 = serratus posterior inferior;
5 = pectoralis major and pectoralis minor;
6 = serratus anterior, rhomboidei, levator scapulae;
7 = latissimus dorsi;
8 = obliquus externus abdominis and obliquus internus abdominis;
9 = iliopsoas, psoas major, and psoas minor;
10 = diaphragma;
11 = quadratus lumborum;
12 = rectus abdominis;
13 = extensores spinalis dorsi.

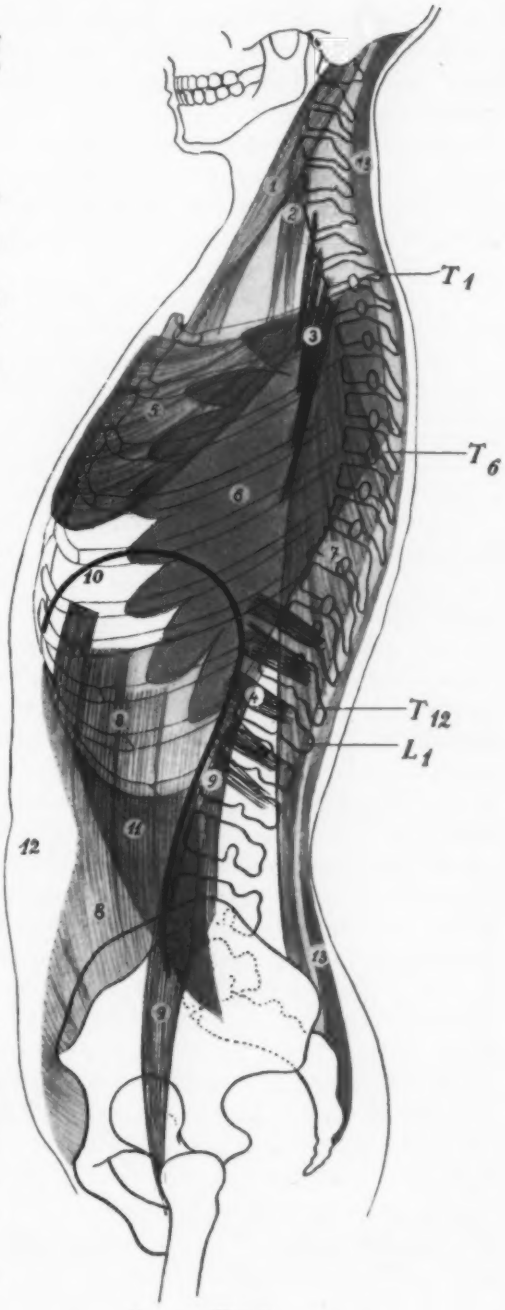

FIG. 9

leverage action on the vertebral column beyond the limits of movement imposed by the vertebral joints themselves.

Scoliosis is relatively insignificant in post-tetanic spinal deformity, because the muscle contractions are almost always bilaterally symmetrical and bend the trunk in an anteroposterior plane. The spine is also far more resistant to a traumatic scoliosis induced by muscle contraction, because the muscles which might produce this have far less leverage, and the resistance of the vertebral column to rotation and lateral bending in such a circumstance is resisted by the ribs and intercostal muscles and ligaments, as well as by the interlocking of the articular processes to prevent lateral motion, especially in the thoracic spine. As Müller[48] has pointed out, in all the processes which lead to a formation of wedge-shaped and flat vertebrae, we find repeatedly sagittal curvatures, whereas scoliosis represents the deformity of particularly resistant vertebral bodies.

Permanent deformity is not the result of latent tetanus or of continued muscle rigidity, but of change in form of the vertebral bodies. When fixation of the kyphos occurs, it is the result of changes in the intervertebral discs.

Thus the typical post-tetanic spinal deformity is an anterior bending of the thoracic spine, with the apex of the bend at the sixth thoracic vertebra, and is caused by a predominating contraction of the anterior trunk musculature, which produces an anteflexion of the spine at this point.

RESISTANCE OF ADULT VERTEBRAE TO THE BENDING FORCE

Indirect Vertebral Fracture

It is well known that muscle action alone can break a bone, and cases of localized tetanus have been known to cause dislocation of the elbow or of the shoulder [70], as well as fracture of the femoral neck [2] and of the forearm [81]. However, fracture of a vertebral body by muscle action is practically unknown, except in tetanus, although this has been reported to have occurred in breeding stallions. If one makes use of the theory of Radmann to explain the mechanism of spinal compression fractures as the result of muscle action incited by external trauma, the susceptibility of the vertebral bodies to fracture by muscle action would be more apparent. According to this theory, the force of a jarring or bending fracture of the spine is not transmitted simply in a vertical direction from one body to another, but its horizontal and vertical components are resisted by a third, represented by a sudden tension occurring in muscles fixed at a point anterior to the spine and contracting reflexly. The contraction of these muscles compresses the anterior surfaces of the bodies in a mechanism similar to that of the tetanic curving of the thoracic spine anteriorly.

It has been shown that the bending force in tetanus acts to produce compression of the anterior portions of the vertebral bodies; this is apparent also from the nature of the deformity. There is still a question, however, as to the possibility of this occurrence in normal vertebral bodies, also as to whether they are defective or incur a toxic damage through the disease of tetanus apart from the mechanical injury. Although occasional authors have found evidence of a disease process in or near the vertebrae preceding the attack of tetanus, it has been generally impossible to find such a predisposing condition. Before taking up the question of developmental defects in the juvenile or adolescent spine which may provide such a background, we may consider the physical and pathological changes occurring through pressure injury to a normal adult vertebra, and the damage which vertebral bodies might incur through tetanus apart from the convulsive trauma.

Physical Changes Induced by Trauma

Messerer [16] and others have found weights of from 200 to 425 kilograms necessary to alter the shape of adult thoracic and lumbar vertebral bodies. Göcke found that weights up to 480 kilograms did not alter the

form of a vertebral body, but, through condensation and increased brittleness of the spongiosa, diminished the resistance to compression and increased the plasticity of the vertebral bodies. Trip-hammer blows in rhythmic succession reduced the elasticity of the bone after a certain time, so that the transient elastic flattening, which at first occurred with each blow, recovered less and less, and the vertebra became brittle and lost its initial resistance to sudden pressure. This corresponds to Lange's experiment (page 20) [47], in which temporary elastic flattening of a vertebral body occurred when pressure up to a certain amount was applied, but beyond this point a lasting deformity was produced by pressure. The tenth thoracic vertebra of a man who was killed by a fall from a five-story building showed less resistance to stress than the corresponding vertebra of a child, although no anatomical changes were present. This is analogous to the loss of temper in iron through hammering and is a physical explanation for diminished resistance of the vertebral body through transgression of the limit of elasticity without initial fracture of the spongiosa.

According to Fick, the fifth thoracic vertebra is the weakest in the entire spine.

The foregoing shows a remarkable resistance of the individual vertebral bodies to force which acts on them in a vertical direction, but it does not account for the occurrence of compression fractures as the result of relatively slight trauma; nor does it consider the impact resulting from the suddenness with which a lesser force might affect the vertebral body. The muscle contraction which causes a vertebral compression is a force that we cannot estimate, nor do we know the resistance of a vertebral body to such a force; and the leverage which is transmitted by the ribs and in the bending of the spine on itself has not yet been measured.

Pathological Changes Induced by Trauma

Immediate

A definite description of anatomical changes induced in vertebral bodies by tetanic convulsions has been made in only two cases. Because of the rarity of such a description, the two cases will be repeated here:

Case of Eberstadt. The patient was a soldier, twenty-nine years old. Two months following shrapnel injury to the elbow, there developed tremor, stiff gait, bilateral clonus, and Babinski reactions. A month later, the patient suffered back pain and convulsions, with bulging of the thoracic cage and prominence of the thoracic spine. Increasing gibbus formation was noted. Roentgenographic examination revealed collapse of the fourth and fifth thoracic vertebrae without localized defect. The patient died in convulsions four months after injury. Autopsy disclosed compression and flattening of the third and fourth thoracic vertebrae. The microscopic report was as follows: "In the affected vertebral bodies, numerous shattered, broken, and collapsed bone trabeculae, which comprise a rather disordered group. In many places, the medullary cavity is replaced by an oedematous vascular fibrillar marrow, which contains some plasma cells and small round cells with much protoplasm. Limited new bone formation with irregular calcification. No evidence of a specific process. Diminished calcium content."

This happens to be the first pathological report of a spinal fracture caused by tetanus.

Later, in 1926, Bäcker published a similar report as the first of its kind. That he described the preceding report as the expression of an osteomyelitis infectiosa, originating in a suppurating gun-shot wound of the elbow, is merely an interesting commentary on the personal factor which so often presents itself in the literature.

CASE OF BÄCKER. A boy, fifteen years old, suffered violent tetanic convulsions following foot injury. Convulsive lumbar lordosis prevented spinal puncture. The patient died two days following the onset. The autopsy report (Schmorl) follows: "Hemorrhage in connective tissue in vicinity of third to sixth thoracic, extending into the posterior mediastinum. Flattening of fourth and fifth thoracic. Extravasation of blood in the bodies of third to sixth thoracic. In profile section: bony portion of fifth thoracic separated from the overlying intervertebral disc by hemorrhage. Fifth thoracic compressed, sixth thoracic somewhat less so, spongiosa strikingly pale and crushed. Fourth thoracic moderately wedge-shaped, spongiosa likewise condensed and pale. Third thoracic only slightly so, and spongiosa crushed and pale only in the lower half.* Intervertebral disc between fourth and fifth thoracic infiltrated with blood. Fifth thoracic projects into the spinal canal. Ecchymosis between dura and posterior surface of vertebral body at this point, as well as a smaller ecchymosis between dura and arachnoid; at this level, meninges and cord oedematous. Microscopically: apart from the mechanical disorder, completely intact bone."

A third case of pathologically verified post-tetanic fracture was added by Randerath in 1936, in which a photograph of the sagittal section of the affected vertebrae showed multiple horizontal fractures, entirely fresh and showing no reaction, in the bodies of the third to the fifth thoracic vertebrae, especially in the fifth thoracic vertebra.

A fourth case was mentioned by Scharsich, who merely stated that a post-tetanic vertebral fracture was pathologically verified.

Delayed

Subsequent changes in the spine can be accounted for by the following analogy: Microscopic callus formation, with infraction and displacement of bone trabeculae, and minute hemorrhages in the vertebral bodies, are occasionally incidental autopsy findings. A more extensive form of this is found in definite vertebral fractures when death occurs shortly after the fracture. Schmorl has described it as follows: "unexpectedly extensive necrosis of the marrow cavity and bone trabeculae, which reaches into the bone tissue far from the line of fracture; this necrosis does not always coincide with the hemorrhagic shattering of the medullary space, but also occurs entirely separate from this". Schmidt described an example of this type in a vertebral body which had retained its form without an alteration that would have been roentgenographically visible. Death was caused in this case by fracture of two thoracic vertebrae. The changes described were found in a third. In another case of Schmorl's, death occurred on the eighth day as a result of fracture of the eighth tho-

* This topographical restriction speaks further for a purely mechanical causation.

racic vertebra. At autopsy, there was found an almost total necrosis of the fourth thoracic vertebra, although little more than the fatal fracture was found in the eighth thoracic vertebra. Schmidt regarded this as an atrophy of bone tissue, which took place not only under the influence of the organization of necrotic hemorrhagic areas, but in the center of these, separated from the activity of living tissue. He blamed the extent of atrophy on the hemorrhagic extravasation and raised the question of the relation of this to traumatic bone cysts and to bone changes in hemophilic joints. Schmidt also described a notable case in which a similar process occurred gradually in several thoracic vertebrae with no clinical trace of trauma. Here hemorrhage and necrosis were present even in bodies which had not lost their contours.

Recovery from such a condition can be associated with callus formation, and it is evident that one here approaches the entity of Kümmell's disease, which is connected not only with an initial external trauma, but with a later continual static trauma. Clinical and pathological analogies can be found in the "march fracture" of the second metatarsal, Köhler's disease of the tarsal navicular, malacia of the os lunatum, etc. The subject of pathological changes following vertebral fractures has been introduced here because they can account for a number of conditions in the spine following tetanus convulsions, whose cause might otherwise be sought in a preceding pathological defect. However, as Schmorl and Junghanns (page 79)[68] have pointed out, an old spondylitis infectiosa could be responsible for a wedge shape or fracture at autopsy, at a time when the original cause was no longer to be seen under the microscope.

Thus, from physical and pathological standpoints, where even a slight change has taken place in a vertebral body without alteration in form, the affected bone is more exposed to damage by the normal daily burden. Where a change in shape has already taken place, the weakened link or bent portion throws the entire chain into static decompensation, and a more definite basis is provided for later changes.

The Contributory Effect of Tetanus Infection

Various authors have spoken vaguely of a possible effect of tetanus toxin or even of the bacilli themselves on the vertebrae. This possibility is to be considered in the two rare examples of tetanic fracture of lumbar vertebrae, already referred to. The possibility of local circulatory disturbance has also been mentioned.

Krinitzki reported that he had produced hypocalcaemia by the injection of tetanus toxin in experimental animals, with a rise of blood potassium in severe cases. Although such a determination may have more value as an indicator for therapy, it could, in combination with the acidosis of tetanus, lead to a drain of the bone-calcium store, which is most labile, and which is the first to be affected in the bones of the vertebral column, particularly in young individuals. Moffatt has demonstrated exaggerated anteroposterior curves and the ease with which com-

pression fractures of the spine occur in nutritional calcium deficiency. He observed that the absence of bony condensation was most marked in the upper and lower margins of the individual vertebral bodies where condensation would otherwise occur as a reaction to the indentation of the elastic nucleus pulposus. Calcium deficiency produces a defect in growing bones in the zone of preparatory calcification, with secondary disturbance in vascularization and absorption of cartilage, and broadening and irregularity of the epiphyseal line (page 83) [47]. This is to be kept in mind in the later consideration of changes occurring in these parts of the vertebral body in children and in adolescents.

The conclusion to be drawn from the foregoing is that the apparently normal adult vertebral column is susceptible to gross or to microscopic compression fractures under the influence of tetanus and tetanic convulsions. This would seem to answer at once the predominance of vertebral changes following tetanus in younger individuals whose spines are less resistant than those of adults, even though their musculature may be correspondingly less well developed. Nevertheless, the muscle force acting on the spine is something we can judge only approximately and we cannot take the extent of damage to the vertebral column as the criterion of this muscle force when a vast number of severe attacks, even those ending in death, do not cause spinal curvature, and when others of lesser degree can produce a deformity. The rarity of post-tetanic spinal deformity and its relatively high incidence in adolescents are explicable neither on a muscular basis nor on the age incidence of tetanus in general.

The basis of weakness in the adolescent spine is rather to be sought in an exaggerated speed of endochondral ossification occurring in the vertebral metaphysis at this time, in which ossification lags behind a predominating growth of columnar cartilage. This will be dealt with in a further paper, but the view that the factors which expose the spine to juvenile kyphosis and post-tetanic spinal deformity are similar is supported by the comparable natures of these two conditions.

POST-TETANIC SPINAL DEFORMITY AND KYPHOSIS DORSALIS ADOLESCENTIUM

In spite of the clinical and roentgenographic similarities between the two conditions, only three writers [12, 82] have considered them comparable. They, however, deny that these conditions are similar for a number of reasons which follow; the author's opinion as to the validity of each reason is stated parenthetically.

1. In post-tetanic kyphosis there are hardly ever changes in the intervertebral discs. (Disc changes do occur, however, and in juvenile kyphosis they are also infrequent. Nuclear herniations occur more frequently in juvenile kyphosis because they are normally found more often at the lower level. Nuclear herniations probably play only a secondary rôle.)

2. Post-tetanic kyphosis is found more often than juvenile kyphosis. (This is contradicted by statistics.)

3. There is an overlapping between post-tetanic kyphosis of slight degree and that of severe grade. (This is just as true of juvenile kyphosis.)

4. Juvenile kyphosis is a primary epiphyseal affection. (The vertebral epiphyses are not the primary seat of the affection. It will be pointed out, however, that a developmental defect of a similar nature is a factor in both conditions.)

5. In juvenile kyphosis, the wedge form of the bodies is blunt, not acute. (This blunt wedge appears in only a limited number of cases of juvenile kyphosis and also in post-tetanic kyphosis.)

6. Irregular opacities are seen in the vertebral bodies in juvenile kyphosis. (These are seen also in the other type.)

7. The kyphos of adolescence is situated lower than that following tetanus. (The difference is only one of location, as shown in Figure 7. The muscle action of tetanic convulsions has already been shown to be responsible for the level of the associated deformity. A comparison of Curves *3* and *4* in Figure 7 shows the static origin of juvenile kyphosis. Such a difference bears no relation to the diminution in functional capacity of the spine which underlies both conditions.)

The following similarities cause one to seek a factor common to both conditions:

1. In most cases, there is a kyphos affecting the thoracic spine. The kyphos is of similar degree and extent and is found in that portion of the thoracic spine that is exposed to the type of stress which is peculiar to each condition.

2. The deformity occurs predominantly during adolescence, and for the most part in males.

3. Although a familial occurrence is seen frequently in juvenile kyphosis, there is little in the history, general physical examination, and later symptoms to suggest a defective physical background or disease process in the spine. Following the appearance of the deformity, the symptoms are referable to a mechanical decompensation of the vertebral column.

4. Both entities are associated with an overburdening of the spine, which extends over a longer or shorter period of time, and the deformity appears in a short time following the first exposure to stress.

5. The changes in the vertebral bodies consist of flattening and wedging, irregularity in density, early appearance of fragmentation in the end-plate regions, indentation of the upper and the lower surfaces, notching of the anterior surfaces, and tendency toward recovery of contour. Although such changes do not occur in all cases, they are present in one condition or in the other in such number that they may be said to be common to both.

6. In both types of kyphosis, fixation and permanence of the deformity are frequent findings.

7. Cases have occurred in which changes in the lower thoracic verte-

brae, characteristic of juvenile kyphosis, have been found subsequent to a post-tetanic deformity above this point.

SUMMARY

Cases have been reviewed and described to show that kyphosis of the vertebral column may follow tetanus, with or without demonstrable fracture of the vertebral bodies. The force initiating this deformity is explained on the basis of the contraction of certain muscle groups during tetanic convulsions. Although there is a greater tendency for vertebral fracture to occur in adults, the majority of post-tetanic kyphoses occur in adolescents in an age group corresponding to that of juvenile kyphosis. The similarity to juvenile kyphosis includes also the clinical and roentgenographic characteristics of both conditions, with the exception of the level of the deformity, and this difference is explained by the "dynamic" level of stress in post-tetanic kyphosis in contrast to the "static" level of stress in juvenile kyphosis. Post-tetanic spinal deformity in adults is the result of a particularly severe and prolonged attack of tetanus. Because it does not seem possible to explain the occurrence, age incidence, and roentgenographic changes in adolescents purely on the basis of the intensity of tetanic convulsions, and because of the striking resemblance to juvenile kyphosis, a common factor of weakness in certain adolescent spines is sought to explain this. Further study has indicated that this factor, most prominent in juvenile kyphosis, is an overacceleration of endochondral ossification during the periods of most active body growth, causing ossification in the metaphyses of the vertebral bodies to lag behind a predominating proliferation of columnar cartilage.

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SERUM PHOSPHATASE—ITS CLINICAL APPLICATION IN DISEASES OF BONE *

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Since the discovery of the enzyme phosphatase, there has been increasing interest in the relation of the activity of the enzyme in the serum to various pathological conditions, notably bone disease. Although its clinical applications are as yet limited, sufficient evidence has been produced in the past few years to establish the importance of serum phosphatase in the differential diagnosis and prognosis of several bone diseases. We became interested in this problem several years ago and our investigations were at first limited to the relationship of serum-phosphatase level to the healing of fractures, the results of which have been published.[11] It is our purpose in this paper to review the literature pertaining to the clinical application of serum phosphatase to bone disease and, in addition, to present the results of our own investigations.

Inasmuch as it has been shown that the enzyme phosphatase is an important factor in bone metabolism, we, as a group of orthopaedic surgeons, should be familiar with its function and variations in certain diseases of the bone. We have been accustomed for years to obtain serum-calcium and phosphorus determinations in bone disease and have known that these are affected to a greater or lesser extent in diseases of bone, but to these must be added a third variable, the serum phosphatase, which undergoes still greater changes.

Robison [14] and his coworkers in 1923 demonstrated that the enzyme phosphatase was capable of hydrolyzing phosphoric esters such as glycerophosphates and hexosephosphates into inorganic phosphates. They discovered the presence of the enzyme in the kidney, the intestinal mucosa, muscle, and plasma, as well as in bone. Growing bone, especially, they found contained a high concentration of the enzyme and they concluded that a relationship existed between the enzyme and bone metabolism.

Kay [9] summarized the evidence in favor of this view as follows: "The enzyme in bone was not confined, however, to the epiphysis but was present in considerable, though lesser, quantities in the shafts of long bones as well. The surprising and striking fact that such a relatively inert tissue as bone should contain this active enzyme, so conveniently situated for the deposition of calcium phosphate, pointed directly to the probability that the enzyme played some specific part in bone formation.

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Up to the date of the discovery of this enzyme in bone, the cause of the deposition of calcium phosphate in this tissue and its non-deposition elsewhere had not been satisfactorily explained. The hydrolysis of some phosphoric ester, the calcium salt of which is readily soluble in water or plasma, by an enzyme present to a greater extent in ossifying cartilage than in any other tissue, leading to the *local* production in the calcifying zone of an inorganic phosphate-ion concentration considerably higher than that in the blood, offered an explanation of calcification which seemed to fit the facts much more closely than the theory of specific adsorption by ossifying cartilage . . . which was one of the less unsatisfactory hypotheses. . . ."

Kay [6, 7, 9], Bodansky and Jaffe [1], and others [13, 16] demonstrated that there was an increase of serum phosphatase in several diseases of the bone. It is known that there are variations of serum-phosphatase activity with other conditions—notably jaundice, nephritis, and accompanying a high carbohydrate diet—and these facts must be borne in mind in interpreting the serum-phosphatase readings. However, up to the present, determinations of serum-phosphatase activity still find their most useful application in the diagnosis of diseases of bone.

It has also been shown that variations in serum-phosphatase activity occur at different age levels, the readings for children being highest with a gradual decrease with advancing age. According to Bodansky and Jaffe, the normal value of serum phosphatase for adults is 2.6 units per 100 cubic centimeters, with a range between 1.5 and 4 units; and for children, 7.2 units per 100 cubic centimeters, with a range between 5.2 and 13 units. The Bodansky method of determination has been used throughout in this study.

The significance of variations in serum-phosphatase activity in the various bone diseases studied is not yet clearly understood. Several theories have been advanced, none of which is entirely tenable. Robison's [15] theory was that the level of the enzyme was an index of the "cellular activities leading to the formation of bone". Kay [8] explained the high plasma phosphatase in disease of bone by "leakage at more than the normal rate, possibly because it is produced in excessive amount in attempted compensation for the lesion". Woodard, Twombly, and Coley [17] concluded that serum-phosphatase activity was "a measure of the amount of new bone formation taking place in the body or of an attempt on the part of the body to form new bone". Bodansky and Jaffe conceded that the higher serum phosphatase of the young was likely due to the greater "cellular activities leading to this formation of bone", but argued that this explanation did not account for the increase of serum phosphatase to the extremely high levels found in rickets or in Paget's disease. They contended that it represents the capacity of bone for cellular activities and that, due to certain stimulations, this capacity is increased with formation of abnormal bone or osteoid tissue, as in the case of Paget's disease and rickets. They found from their studies that

destruction of bone *per se*, unless accompanied by new bone or osteoid formation, was probably not associated with a marked rise of serum phosphatase.

To ascertain the diagnostic and prognostic value of phosphatase determination, an analysis has been made of the readings taken on several hundred cases showing bone lesions, the results of which follow.

FIG. 1

PAGET'S DISEASE

In Paget's disease with multiple bone involvement it has been shown that the serum-phosphatase activity may rise to twenty or more times the normal figures, while the calcium and phosphorus content remains normal. Bodansky and Jaffe reported levels of from 15 to 125 units for the polyostotic type and of from 5 to 23 for cases with localized lesions. Gill and Stein [4] have suggested the use of serial phosphatase determinations as an index of the progress of the condition. They found that with a diet low in calcium, low in phosphorus, and high in magnesium there was a tendency toward disappearance of the symptoms and a gradual decrease in the serum-phosphatase activity. Bodansky and Jaffe noted in

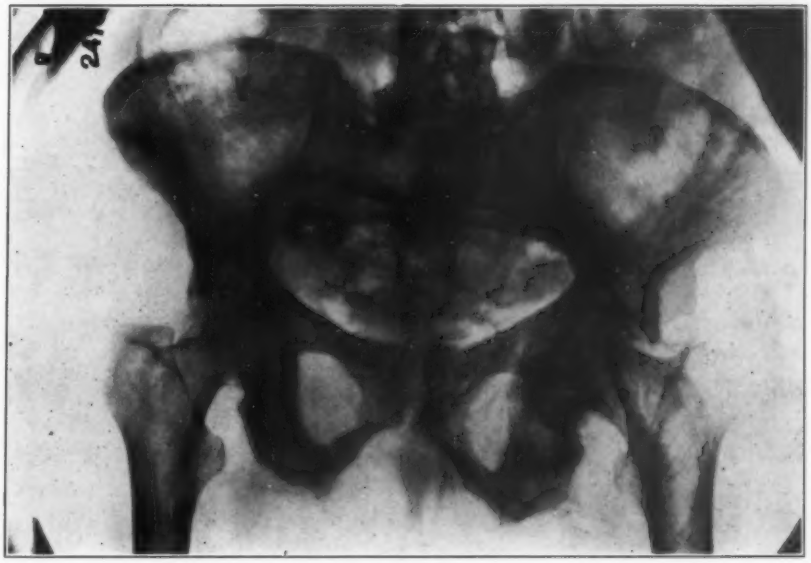

FIG. 2

their study of Paget's disease that the oldest patients showed the lowest values for serum phosphatase, which they believed to be due in part to spontaneous healing by sclerosis.

The levels of serum phosphatase in our series of Paget's disease (Table I), while relatively lower than those of Bodansky and Jaffe, corresponded in that the higher values were found in the polyostotic type and there was a tendency for the level to be lowered with healing by sclerosis.

An unusually high level of serum phosphatase accompanying an obscure bone lesion is evidence suggestive of Paget's disease. Yaguda [18] reported a case which was originally diagnosed as metastatic carcinoma, but which showed an increased phosphatase. Later developments showed the localized bone condition to be Paget's disease. One case of our series (Case 2, Table I) is illustrative of the diagnostic value of serum phosphatase. This woman was seen because of back symptoms, and roentgenograms revealed a destructive lesion involving several of the vertebral bodies. (See Figure 1.) Routine calcium, phosphorus, and phosphatase determinations were obtained and the phosphatase reading was found to be 11.3 units. Paget's disease was then suspected and confirmed by roentgenograms of the pelvis and the long bones. (See Figure 2.)

HYPERPARATHYROIDISM

This condition is characterized by a high-calcium, low-phosphorus, and high-phosphatase content of the serum. As is well known, the blood chemistry returns to normal shortly after removal of the parathyroid adenoma. The average serum-phosphatase level is lower than that seen in Paget's disease, the average for our series being 8.3 units. (See Table II.)

TABLE I

OSTEITIS DEFORMANS

Case	Sex	Age (*Years*)	Calcium	Phosphatase	Bones Involved
1. E. P.	Male	56	10.2	20.40	Pelvis, femur.
2. N. M.	Female	63	10.0	11.30	Pelvis, femur, spine
3. J. D.	Male	55	10.0	6.24	Pelvis, spine
4. G. E.	Male	63	9.8	35.05	Both tibiae
5. B. K.	Female	52	9.7	31.50	Pelvis, tibia
6. E. J.	Male	41	9.4	6.62	Humerus (fracture)
7. M. R.	Female	59	10.2	7.30	Tibia
8. W. S.	Male	63	9.8	2.62	Tibia (fracture)
9. D. W.	Male	45	9.0	37.00	Humerus (fracture)
10. J. LeB.	Male	55	10.2	19.10	Humerus (fracture)
11. A. S.	Female	73		11.90	Lumbar spine
12. F. B.	Male	56	9.3	6.92	Pelvis

On one of these cases (Case 3, Table II) daily blood-chemistry determinations were obtained before and for several weeks following operative removal of the adenoma. (See Figure 3.) As was to be expected, the serum calcium rapidly returned to normal following operation. The phosphorus showed only a slight rise, but was not characteristically low prior to operation. We are unable to account for the unusual increase in phosphatase activity occurring after operation and reaching a peak of 18.8 units two weeks later. This would seem to suggest an increased cellular activity following removal of the adenoma, but was probably due to increased carbohydrate metabolism, as the patient received almost daily intravenous injections of glucose.

TABLE II

OSTEITIS FIBROSA CYSTICA

Case	Sex	Age (*Years*)	Calcium	Phosphatase	Bones Involved
1. E. D.	Female	51	12.60	10.72	Femur, forearm
2. J. P.	Male	49	10.20	6.82	Mandible
3. J. H.	Male	51	18.40	7.36	Spine, femora

FRACTURES

In a previous publication [11], one of us (C. L. M.) analyzed serial serum-phosphatase determinations in a large series of fractures. For the present discussion on fractures, we are taking the liberty of quoting freely from this article.

"Regen and Wilkins [12], Botterell and King [2] in experimental work on animals have shown that the phosphatase activity of bone at the site of fracture was greatly increased as compared with that of bone from other sites in the same animal. They found that the increase may be as much as ten to twenty times normal and reached its maximum about three weeks following fracture." That there is an increase in the serum phosphatase following fractures has been demonstrated by several investigators [1, 5, 8, 10].

The purpose of our investigation was to determine:

1. If there was a consistent rise in serum-phosphatase activity following fractures.

2. If the rise was not consistent, was there any correlation between the level of serum phosphatase and (*a*) the location of the fracture, and (*b*) the extent of the injury.

3. If the serum-enzyme level could be used as an index of the rate of healing of the fracture and as a prognostic sign in the development of delayed or non-union.

Serial determinations were made the day following fracture and at weekly intervals for the next three weeks. It was found that in the majority of fractures there was an increase in serum-phosphatase activity, but that this was not consistent. The average phosphatase levels for the seventy-five cases studied were as follows: on admission, 3.74 units; seventh day, 4.43 units; fourteenth day, 4.69 units; twenty-first day, 4.77 units.

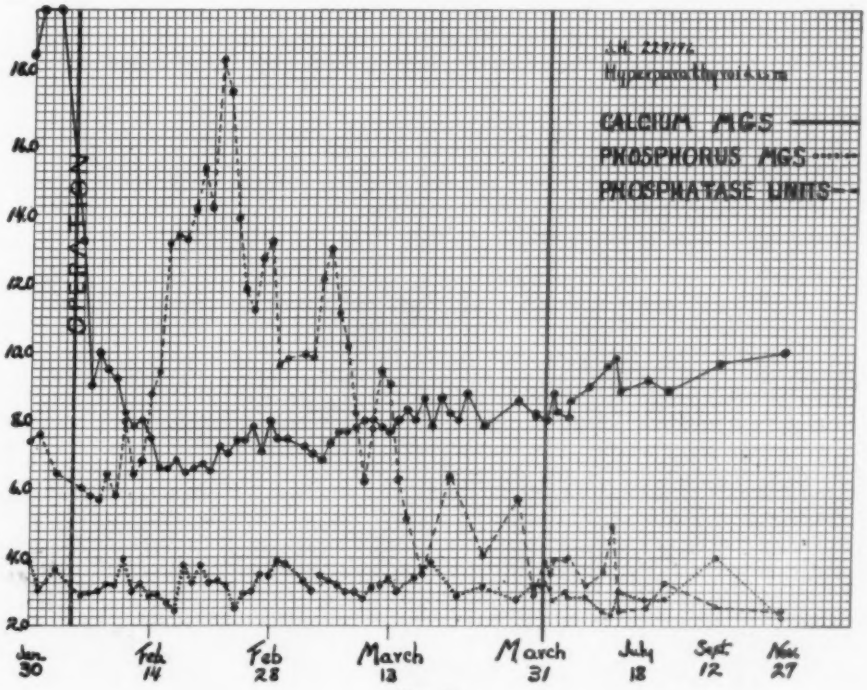

FIG. 3

TABLE III

BONE TUMORS (PRIMARY AND METASTATIC)

Case	Sex	Age (*Years*)	Calcium	Phosphatase	Tumor	Bone Lesion	Bones Involved
1. J. M.	Male	39	9.2	2.64	Osteogenic sarcoma	Lytic	Femur
2. N. M.	Male	48	10.2	7.04	?	Lytic	Spine
3. M. W.	Female	59		4.26	Carcinoma of bladder	Lytic	Tibia
4. F. C.	Male	62		2.37	?	Lytic	Spine
5. M. S.	Female	40	10.6	2.32	Giant-cell tumor	Lytic	Femur
6. A. T.	Male	41	10.2	3.54	Giant-cell tumor	Lytic	Femur
7. K. S.	Female	57	9.2	2.24	Lympho-sarcoma	Lytic	Spine
8. S. L.	Female	52	8.4	4.49	Carcinoma of breast	Lytic	Femur
9. M. D.	Male	14	10.2	3.12	Sarcoma	Lytic	Ilium
10. W. F.	Male	82	8.2	9.56	Carcinoma of prostate	Osteo-blastic	Ilium

There was found to be no correlation between the extent of the injury or the location of the fracture and the level of the phosphatase activity. Lastly, it was found that the serum-enzyme level could not be used as an index of the ability of the fracture to heal, as many cases of delayed and non-union showed relatively high readings.

BONE TUMORS

That there is an elevation of serum phosphatase accompanying certain tumors of bone has been demonstrated by various observers. Franseen and McLean [3] analyzed a series of bone tumors and found that there was significant elevation of the serum-enzyme activity in the osteoblastic

TABLE IV

TUBERCULOSIS OF BONE (CHILDREN)

Case	Sex	Age (*Years*)	Calcium	Phosphatase	Site of Lesion	Duration	Status
1. E. W.	Female	6½	10.4	6.00	Spine	2½ years	Active
2. S. B.	Female	15	9.8	4.35	Hip	10 years	Active
3. B. C.	Male	4	9.8	4.21	Spine	8 months	Active
4. D. W.	Male	1½	10.4	3.59	Spine	4 months	Active
5. J. P.	Male	10	10.8	4.64	Spine	8 months	Healing
6. G. L.	Male	3½	9.7	3.69	Spine	1 year	Active
7. E. T.	Male	1	9.6	2.58	Ulna, tarsus	6 months	Active
8. W. B.	Male	9	9.4	4.22	Spine	6½ years	Active

TABLE V

TUBERCULOSIS OF BONE (ADULTS)

Case	Sex	Age (*Years*)	Calcium	Phosphatase	Site of Lesion	Duration	Status
1. M. D.	Female	33	10.0	4.42	Spine	1½ years	Active
2. K. M.	Male	30	10.0	1.90	Spine	9 years	Active
3. R. J.	Female	18	9.8	2.16	Spine	5 years	Active
4. J. S.	Female	22	10.0	2.12	Spine	12 years	Healing
5. E. G.	Female	35	10.2	3.02	Spine	6 months	Healing
6. H. D.	Male	16	10.0	3.79	Spine	5 years	Healing
7. I. P.	Male	30	10.2	2.33	Spine	4 years	Active
8. H. B.	Male	15	10.0	4.35	Spine	2 months	Active
9. J. T.	Male	51	9.4	3.22	Hip	2 years	Active
10. K. M.	Female	35	9.6	2.16	Spine	2½ years	Healing
11. E. C.	Male	40	9.0	3.46	Spine	5 years	Active
12. R. A.	Male	27	10.1	2.14	Spine	3 months	Active

type of osteogenic sarcoma. They demonstrated that, with surgical removal of the tumor mass in this type of osteogenic sarcoma, there was a rapid fall of serum phosphatase to normal, to become elevated again with recurrence of the tumor. They reported no increase in the serum-enzyme activity in cases of multiple myeloma and elevation in cases of metastatic carcinoma of bone, and suggested that the serum-phosphatase level might be of use in the differential diagnosis of these conditions. Woodard, Twombly, and Coley concluded that the bone-forming characteristics of a tumor are of more importance than its malignancy in determining whether its presence will give rise to an elevated serum phosphatase. They found a high level of serum-phosphatase activity in the osteoblastic type of osteogenic sarcoma and in the osteoblastic type of metastatic carcinoma and little or no elevation in the osteolytic types. They suggested the use of serum-phosphatase determinations in differentiating between osteoblastic osteogenic sarcoma and chondrosarcoma, and between osteoma and

TABLE VI

OSTEOMYELITIS

Case	Sex	Age (*Years*)	Calcium	Phosphatase	Bones Involved
1. P. L.	Male	17	9.8	2.04	Femur
2. J. C.	Male	31	9.6	2.78	Femur
3. C. H.	Male	30	9.8	2.11	Femur
4. W. C.	Male	20	9.6	1.30	Femur
5. J. McN.	Male	28	10.4	4.02	Femur
6. A. T.	Male	15	9.6	2.37	Humerus
7. M. S.	Female	15	10.2	3.66	Tibia

an old myositis ossificans,—tumors which may show almost indistinguishable roentgenographic pictures.

Table III gives figures for various types of bone tumors investigated in our Clinic. It would appear that in general there is little or no elevation of phosphatase activity accompanying osteolytic lesions. Unfortunately, no biopsy was obtained and no primary lesion discovered in Case 2 (N. M.), showing a slight elevation of serum phosphatase.

BONE AND JOINT TUBERCULOSIS

As would be expected with a purely destructive lesion of bone, no elevation of serum-phosphatase activity was found in children or in adults with bone and joint tuberculosis. (See Tables IV and V.) The average level of serum phosphatase in the children studied was somewhat below normal, which might be explained on the basis of poor nutrition. There seemed to be no correlation between the activity or stage of the lesion and the phosphatase level. It was not felt, therefore, that the serum-phosphatase determinations in this condition were of prognostic value.

OSTEOMYELITIS

Several observers have reported a slight rise in the serum-phosphatase activity accompanying osteomyelitis. One might expect a slight rise during the regenerative process with the formation of new bone, and Bodansky and Jaffe suggested this as an explanation for the elevation when present. However, we found the levels in our series to be within normal limits, whether in the acute or in the regenerative stage. (See Table VI.)

RICKETS

Bodansky and Jaffe reported a series of twenty-seven cases of active rickets with serum-phosphatase levels ranging from 30 to 190 units, depending upon the severity of the condition. They found that with adequate treatment there was a marked decrease of serum phosphatase associated with other evidence of rapid healing. They concluded that a normal serum-phosphatase level was evidence of a healed process.

SUMMARY

1. In reviewing the relation of serum-phosphatase activity to the more common diseases of bone, it has been found, in general, that there is an increase in serum-phosphatase activity accompanying the formation of unusual amounts of new or of abnormal bone. There appears to be little or no increase associated with the purely destructive lesion of bone.

2. Determinations of serum phosphatase are an important aid in the diagnosis and differential diagnosis of Paget's disease, osteitis fibrosa cystica, and tumors of bone.

3. The level of serum-phosphatase activity cannot be used as an index of healing or of the ability of a fracture to heal.

4. No significant changes in serum-phosphatase activity were noted in cases of bone and joint tuberculosis and of osteomyelitis.

5. Serial phosphatase determinations are suggested as a criterion of effective therapy in Paget's disease, hyperparathyroidism, osteoblastic osteogenic sarcoma, and rickets.

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RUPTURE OF THE SUPRASPINATUS TENDON *

BY LEO MAYER, M.D., NEW YORK, N. Y.

In his book on the shoulder, Codman reports that, despite his many years of study, he has never had an opportunity of operating on an early case of ruptured supraspinatus tendon. His knowledge of the pathology was, therefore, gained entirely from observations of late cases. These facts were emphasized by Codman in a lecture delivered before the New York Academy of Medicine in the spring of 1935. By a peculiar coincidence, on the day after the lecture I had occasion to diagnose a tear of the supraspinatus tendon which had occurred less than forty-eight hours before, and, during the next three months, three similar cases came under my observation.

Small though the series is, the study of these cases has taught me so much, and my errors have cost me so dearly, that it seems worth while to present these experiences, if for no other reason than to prevent others from making the same mistakes.

Of the symptomatology, nothing needs to be said. It is all described so clearly in Codman's book that repetition is unnecessary. The observed pathological changes are, however, important. Common to all four cases was a complete tear of the supraspinatus tendon. This occurred at the bony insertion,—only a few minute shreds of tendon were found adherent to the greater tuberosity. The proximal end of the tendon had retracted upward and inward about one and one-half inches. It was hard to distinguish the tendon from the torn capsule of the shoulder joint, which, like the supraspinatus tendon, was found ruptured in all four cases. The torn capsule formed a circular rent approximately one and one-half inches in diameter. The upper border of this rent was remarkably smooth, evidently due to the fact that the smooth surface of the bursa had wrapped itself over the edge of the tear. Through this rent the cartilage of the head was visible. In the first case the bursa was filled with blood clot; in the other three no evidence of bleeding was found. In two cases the infraspinatus tendon was torn away with the supraspinatus. In one case the long head of the biceps was completely torn just as it entered the joint, and in another this tendon was frayed and partly torn.

OPERATIVE TECHNIQUE

In the first three cases I made a straight incision downward from the acromion directly in line with the torn supraspinatus. This gave adequate exposure only after splitting the deltoid for more than three inches. At the time of the operation this caused me no misgivings, but in the aftercare of these patients I noted a marked weakness of the anterior fibers of

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 12, 1937.

the deltoid. This must, I believe, have been caused by division of minute branches of the circumflex nerve passing forward in the substance of the muscle. Certain it is that it took months of postoperative treatment before the muscle recovered, and in Case 2 it never regained its full strength. For this reason, in the fourth case I avoided splitting the deltoid by running the incision further anterior between the pectoralis major and the deltoid. To gain adequate exposure, about one inch of the clavicular portion of the deltoid was stripped away from the clavicle subperiosteally. By rotating the arm internally, the greater tuberosity was brought into the wound and, by adequate retraction, the proximal stump of the torn supraspinatus could be reached.

FIG. 1

This illustrates the manner of passing the fascial strand through the torn supraspinatus tendon and capsule above and the greater tuberosity of the humerus below.

The repair of the torn capsule of the supraspinatus tendon was accomplished in the first three cases by passing three silk mattress sutures through drill holes in the greater tuberosity and the upper margin of the capsule. Attempts to tie these sutures and to approximate the edges of the capsules were futile until the arm was abducted 120 degrees. In other words, despite the short period of time between the injury and the operation, so much retraction had occurred that the tension of a strong suture was insufficient to overcome the shortening. Conversely, after the sutures had been tied, the attempt to lower the arm to the side of the body caused the sutures to tear out. It was, therefore, necessary to immobilize the arm in abduction of 120 degrees.

For this reason, the after-treatment presented a serious dilemma. If immobilization in the abducted position were continued unduly long, an abduction contracture would ensue; if, however, the arm were brought down too soon, the sutures would not hold and the supraspinatus, together with the capsule, would again be torn away from the greater tuberosity. By analogy with the healing of tendons after transplantation on the foot, I figured that in two weeks a fair degree of union would be present and, therefore, in the first three cases I instituted gentle active and passive motions of the arm at the end of that period. Plaster splints which held the arm abducted about 60 degrees were used between the exercise periods. Despite the cooperation of the patients and the assiduity of my physiotherapists, the results were disappointing. In Case 1, after six months of treatment, active abduction was possible only to 90 degrees; in Case 2, to

120 degrees; in Case 3, to about 130 degrees. Passively there was little or no restriction and the patients did not complain of pain, but the shoulders were far from normal.

In treating my fourth patient, who fortunately did not come to me until I was aware of my mistakes, I made a number of important changes in the technique. The first was the use of the anterior incision running between the pectoralis major and the deltoid, instead of the straight incision, splitting the deltoid fibers. Next, I decided not to rely upon silk, but to use a strong fascial suture for the repair of the torn capsule and tendon. Threaded on a Gallie needle, these fascial strands, three-quarters of an inch wide, were passed through drill holes in the tuberosity and the upper margin of the capsule (Fig. 1). With the arm abducted 120 degrees, they were drawn through and fastened by a No. 3 chromic-gut stitch. Finally, instead of mobilizing the arm at the end of two weeks, I waited four weeks. An anxious two weeks followed, for it was at first impossible for the patient to lower the arm to less than 90 degrees. Gradually, however, by means of continuous gentle traction downward, the abduction contracture gave way. Of course, active exercises for the abductors were kept up rigorously. The final result was a perfect range of motion, despite the fact that this fourth case was complicated by a tear of the infraspinatus.

The lessons to be learned from my brief series are the following:

1. Complete tear of the supraspinatus tendon can be diagnosed and requires operative treatment.

2. It is frequently complicated by injuries to other tendons, either the infraspinatus or the biceps.

3. The incision should avoid injury to the deltoid. My own experience favored an anterior incision running between the pectoralis major and the deltoid, with a slight stripping of the clavicular portion of the deltoid.

4. Fascia, not silk, should be used for the repair, and this should be passed through drill holes in the greater tuberosity.

5. The shoulder should be immobilized in 120 degrees of abduction for four weeks. An abduction contracture will probably ensue, but this will yield to treatment within several weeks.

6. The period of postoperative treatment is likely to last three or four months before normal range of motion and good return of strength can be expected.

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RUPTURE OF THE SUPRASPINATUS—1834 TO 1934

BY E. A. CODMAN, M.D., BOSTON, MASSACHUSETTS

Orthopaedic surgeons are beginning to take an active interest in lesions of the shoulder, and particularly in the one mentioned in the above title. This is indicated by the attendance at a symposium on the shoulder, held by the American Academy of Orthopaedic Surgeons in January 1937, at Cleveland, Ohio. Moreover, since the January number of this essentially orthopaedic Journal contained a fourteen-page article on "Rupture of the Supraspinatus", one senses editorial recognition of the assumption of responsibility for undertaking to keep its readers informed of progress in this field. This is another indication of interest in the last joint to be relinquished by general surgery to orthopaedic surgery, and is tantamount to an opinion that in hospitals the orthopaedic departments, rather than the general surgical departments, should be held responsible for the treatment of shoulder injuries,—a field in which little interest has been displayed by anyone. The immense cost to industry of neglected shoulder injuries (now considered more important than the patient's pain) demands that someone should assume the duty of caring for these cases and studying out methods of treating them effectively.

It matters little that the author of the article in the January issue, H. Alan Skinner, is a professor of anatomy and not an orthopaedic specialist. No doubt his interest in the subject was aroused by some of his clinical colleagues whose good-natured misstatements led him to begin his paper with the following sentences: "Separation of the supraspinatus from its attachment to the humerus is a condition which has been recorded by various writers, notably by Codman of Boston, who was one of the first to recognize the prevalence and importance of the condition. There has been a general tendency to accept it clinically as the direct result of trauma without inquiring into the possibility of other etiological factors. Observations upon cadavera, in this Department and elsewhere, suggest a more wide-spread disturbance than mere rupture of a muscle." A few years ago I would have modestly admitted that the first sentence in this quotation was correct, but my eyes have now been opened by a paper, written over 100 years ago, which seems to me so good that I have requested the Editor of this Journal to reprint it in full. This paper shows that an English anatomist, J. S. Smith, had, in 1834, made the essential observations which were the foundation of my 500-page book, "The Shoulder", published in 1934. Nearly the whole of Skinner's article (which, I submit, is nevertheless a very good one) was also covered by this century-old communication, although the word "supraspinatus" was not mentioned in its title. This paper by Smith had eluded me, as well as the literary bureau of the American College of Surgeons, whom I had employed to search for references to the supraspinatus. It appeared first in the English

Medical Gazette in 1834 and was reprinted in the *American Journal of Medical Sciences* in the following year. I am indebted to K. O. Haldeman and Ralph Soto-Hall, of San Francisco, for calling my attention to it in their excellent article, "Injuries to Muscles and Tendons".

These authors may be credited with disinterring this early paper, although I may at least claim a part in having previously resurrected its subject and in showing the importance of such injuries in modern industry. It was my interest in such lesions which induced Akerson to look for this lesion in a series of cadavera, and perhaps influenced Keyes to do so likewise. However, Meyer's work was quite independent, as was part of Fowler's. At any rate, Akerson at Harvard, Keyes at Washington University, Meyer at Stanford University, Fowler at St. Francis Hospital, Evanston, Skinner at the University of Western Ontario, and, no doubt, others have now confirmed Smith's century-old findings, although the conclusions each has drawn have differed in some degree. The findings in all these studies are essentially the same,—*i.e.*, varying percentages of defects in the capsule of the shoulder joint at or about the region of the insertion of the supraspinatus tendon. Frequently the long biceps is also involved, having become detached from the glenoid rim and having formed a new attachment in the bicipital groove. When a defect is large, it forms a communication between the true joint and the subacromial bursa. All investigators agree on the description of these lesions and on the fact that they occur so frequently that anyone who will search for them in elderly subjects will not have to examine many before he will find one, and it is quite likely that he will find a similar one in the other shoulder of the same subject. As a rule, these defects have a thin falciform edge, adapted to the cartilage beneath, reminding one of the edges of the semilunar cartilages of the knee joint. This falciform edge is interpreted by Meyer to be part of the original tissue left after the wearing away of the tendons by repeated friction in elevation of the arm as the tuberosity rubs against the acromion. My own opinion is that these edges are newly formed tissue with which nature has attempted, vainly, to fill defects caused by rupture and retraction of the tendons. This opinion is founded on observation at operation at periods varying from a few weeks to a few years after the history of a severe shoulder injury, and by successful results after suture of these defects.

I shall not go into further detail, for my arguments are fully set forth in my book. My present purpose is to show that similar observations, which were made in a dissecting room over 100 years ago, were accurately described and were, I believe, more correctly interpreted than such findings have been by our modern anatomists, Meyer and Skinner.

I feel that it is of great importance that the question of whether these falciform edges are remnants left after attrition or are the results of efforts at repair of ruptures should be definitely decided. If, as I believe, they are traumatic, much pain and disability, as well as great economic loss, may be avoided by their prompt recognition and repair.

The following paper by Mr. J. S. Smith, published in the *American Journal of Medical Sciences* for May 1835 (Volume XVI, page 219) is reprinted in full.

PATHOLOGICAL APPEARANCES OF SEVEN CASES OF INJURY OF THE SHOULDER-JOINTS WITH REMARKS

The *Medical Gazette* for May 24th last, contains the following interesting contribution, from John G. Smith, Esq., to our knowledge of the pathology of the shoulder-joint. Mr. S. is unable to give any previous history of the different cases; the whole of them occurred in bodies brought to his theatre for dissection.

"Case I. In the body of a man brought to the dissecting-room, under the old system of violation of the grave, in the month of February, 1832, the following pathological condition of the left shoulder-joint was observed:—

"On making a transverse section in the centre of the deltoid muscle, for the purpose of reflecting it, the bursa situated beneath was observed to be much larger than usual, very much thickened, and communicating with the general cavity of the shoulder-joint by a large irregular opening. On further examination, it was noticed that the tendinous insertion of the subscapularis muscle had been entirely torn away from the lesser tubercle; the supra-spinatus, infra-spinatus, and the teres minor muscles, had likewise been completely detached from the greater tubercle. The tendon of the long head of the biceps had been torn away from the upper part of the glenoid cavity, and entirely withdrawn from the joint: it was found to be firmly attached to the anterior margin of the bicipital groove. The head of the humerus moved freely in all directions on the glenoid surface of the scapula, and the size of the cavity of the joint was much increased, from the extensive laceration of the capsular ligament; it included the whole of the neck of the bone and both tubercles. The appearance of thickening of the capsule below would seem to indicate that it had likewise suffered laceration in this situation at the time of the injury. A small portion of the outer margin of the glenoid cavity had been fractured off, and, with the under surface of the acromion process, and the tubercles of the humerus, were partially covered with portions of enamel-like or porcelain secretion; and numerous bands of organized fibro-ligamentous substance extended across the cavity of the joint in different directions. There was a fracture of the humeral extremity of the clavicle, which extended into its articulation with the acromion.

"Case II. Mary B. . . . , aet. 30, died of consumption in St. George's Work-house, and was removed to the theatre for dissection, in November, 1832, under the new regulations provided by the Anatomical Bill.

"The left shoulder-joint presented the following appearances:—The bursa beneath the deltoid muscle communicated, by a large irregular opening, with the general cavity of the joint: the tendon of the subscapularis muscle was partially torn from the lesser tubercle of the humerus, but the insertions of the supra and infra-spinatus muscles and the teres minor, remained perfect. The round tendon of the long head of the biceps muscle was ruptured, leaving a portion, about half an inch in length, attached to the upper part of the glenoid surface: the lower portion of the tendon had been drawn from the cavity of the joint, and lay firmly attached to the margin of the bicipital groove. The ruptured extremities of the tendon were perfectly smooth and rounded, and the superior portion had become much flattened: small bands of fibro-ligamentous structure were observed, but none of that peculiar enamel-like secretion noticed particularly in the preceding case.

"Case III. Ann D. . . . , aet. 38, died January 1st, 1833: removed from St. George's Work-house, for the purpose of dissection, under the new regulations.

"The following account of the appearances of the right shoulder-joint is extracted from the notes entered at the time, in the dissecting-room journal, by Mr. G. Knox who dissected the extremity. On removing the deltoid muscle, the head of the humerus came into view, presenting a larger surface of bone than usual: on further examination,

it was found that the tendon of the subscapularis muscle had been partially torn away from the lesser tubercle, and the original insertions of the supra-spinatus, infra-spinatus, and teres minor muscles, had been completely separated from the greater tubercle. The tendon of the long head of the biceps had also been torn from its origin, and had become attached to the upper part of the bicipital groove.

"The under surface of the acromion process was found hardened by the friction of the head of the humerus, and covered by a peculiar enamel-like secretion. The capsular ligament appeared unusually thick at the lower part, which gave rise to the idea it had been lacerated at the time of the injury, and had become reunited by the effusion of coagulable lymph.

"CASES IV AND V. Catherine S. . . . , aet. 56, died February, 1833; was removed from St. George's Work-house, under the new regulations, with a medical certificate signed 'sudden death'. She was a short, stout, muscular subject, and, upon inquiry, proved to have been a hard-working woman at the wash-tub up to the time of her death. The shoulder-joints presented the following appearances:—

"*In the right shoulder:*—The bursa beneath the deltoid muscle communicated with the general cavity of the joint, by a jagged irregular opening about the size of a half-crown. The tendon of the subscapularis muscle was torn from the lesser tubercle, and the tendon of the supra-spinatus muscle detached from the greater tubercle; both having become united with the common capsule. The tendon of the long head of the biceps had been torn from the upper part of the glenoid cavity, withdrawn from the joint, and found to be firmly attached by ligamentous structure to the margin of the bicipital groove. There were a number of small exostoses on the tubercles, covered with the enamel-like secretion, which corresponds to a similar appearance on the under surface of the acromion process.

"There was an oblique fracture of the acromion process of the scapula, which had separated about an inch of its expanded extremity; it had not united by bone, but had formed an artificial joint through the medium of cartilage, and was further strengthened by a fibro-ligamentous capsule.

"The appearance of the biceps muscle was very remarkable, and first directed the attention to the condition of the joint; the portion of the belly of the muscle appertaining to the long head, was remarkably short, and the short head, unusually developed, appeared in great measure to supply the place of the other.

"*In the left shoulder:*—On dividing the deltoid muscle, the bursa at its under surface was found very much thickened and enlarged, and an opening observed which communicated with the articulation. On further examination, this opening was found to be caused by a partial separation and detachment of the supra-spinatus and subscapularis muscles, from the larger and lesser tubercles; the surfaces from whence they had been torn being within the capsular ligament. The inner surface of the capsule presented a very rough fibrous appearance, occasioned by the portions of the lacerated tendons; the synovial membrane presenting small villous productions, the result, apparently, of organized lymph.

"The tendon of the biceps was wanting in the joint, having been torn through and divided into a number of fibres, which were attached to the upper part of the bicipital groove; small bony exostoses had been thrown out on the tubercles, and the cartilaginous surfaces of the humerus and scapula were here and there covered by small patches of the enamel-like secretion.

"The acromion process of the scapula had been fractured precisely in the same situation as that of the opposite side, and formed a similar artificial joint.

"CASES VI AND VII. Thomas K. . . . , aet. 40, died April, 1834; removed from the Islington Infirmary, with a medical certificate signed 'Consumption'.

"*In the right shoulder:*—The bursa beneath the deltoid muscle communicated by an irregular opening with the general cavity of the joint. The tendon of the subscapularis muscle was entirely detached from the lesser tubercle, and the fibres of the muscle itself were drawn downwards from the venter of the bone, presenting a small cavity

beneath, lined by an irregular fibro-ligamentous structure, and communicating with the articulation. The tendon of the supra-spinatus muscle was torn from the greater tubercle, the infra-spinatus and teres minor muscles remained attached; but the muscles appear, at some former time, to have suffered severe tension.

"The tendon of the long head of the biceps muscle was not separated from its origin, but displaced from the groove, and lay loose in the inner part of the cavity of the joint; it is expanded, and bears evidence of having been subjected to pressure and friction; one surface, which corresponds to the head of the bone, is smooth and polished, the other presents a bundle of silvery cords, which may be spread out upon the finger three quarters of an inch in width; the bicipital groove is nearly filled with a fibro-ligamentous substance, similar in structure to numerous small bands, which extend across the joint in different directions, from one point of the synovial membrane to another.

"The capsular ligament had been much stretched, and will readily allow the head of the humerus to be displaced under the coracoid process of the scapula, resting upon the inner margin of the glenoid cavity. There is no distinct evidence of the capsule having been ruptured in any other situation than that already mentioned, communicating above with the bursa beneath the deltoid muscle. There were small bony deposits about the tubercles of the humerus, which were within the general capsule, and here and there small patches of that peculiar porcelain secretion.

"*In the left shoulder:*—The bursa beneath the deltoid muscle was found very large, and its parietes thickened, but it did not communicate with the general cavity of the joint, being separated by a thick layer of lymph. The capsular ligament was perfect, but very capacious, and apparently thicker than natural. The head of the humerus moves very freely in its socket, and may be easily drawn beneath the inferior margin of the glenoid cavity. The tendon of the subscapularis muscle is torn from the lesser tubercle, and the fibres are drawn from a considerable part of the venter of the bone. The tendons of the supra-spinatus, infra-spinatus and the teres minor muscles, remain attached to the greater tubercle, but their fibres have evidently been, at some former time, very much stretched.

"The tendon of the long head of the biceps, as in the preceding case, was permanently displaced from the bicipital groove, and lay at the inner and lower part of the joint, playing over a smooth part of the lesser tubercle; one surface is perfectly smooth and glistening, the other is a flattened band of silvery fibres. There are a number of fibro-ligamentous bands of organized lymph stretching across from one point of the capsule to another. The bicipital groove is nearly obliterated by the same structure, and portions of ossific matter have been deposited.

"*Remarks:*—There are several points of extreme interest in the foregoing cases, connected with the pathological condition of the shoulder-joint consequent upon severe injuries, which present themselves for consideration; and I conceive might be attended with a very useful lesson, if we are careful to avoid all hasty opinions, and only select such practical inferences which may be essential in accounting for many circumstances attending accidents of the shoulder-joint.

"It may assist us in forming a right judgment of the case, point out the most rational method of treatment, and enable us to prevent many bad consequences which frequently follow injuries of this important articulation.

"The first point which suggests itself is, that a severe blow, strain, or dislocation, is more frequently accompanied with severe local injury of the muscles and tendons, in the immediate neighbourhood of a joint, than we should be otherwise inclined to suppose.

"I have formed this opinion from the circumstance, that the seven cases of severe injuries of the shoulder, described above, occurred in the comparative small number of dissections, not exceeding forty individuals; and I think I may therefore safely infer, that these effects consequent upon severe accidents more frequently happen than are suspected, and from inadvertency or other causes are entirely overlooked in the ordinary dissection of bodies.

"It is a curious fact, that in two instances both joints of the same individual should

have presented nearly similar appearances, and that the same cause should probably have produced exactly similar results.

"The frequency, in these cases, of the rupture, or tearing away from its origin, of the tendon of the long head of the biceps muscle, and its subsequent withdrawal from the joint into the bicipital groove, and its complete and permanent displacement in two instances, are facts in themselves of great practical importance.

"The separation of the tendon of the subscapularis muscle from the lesser tubercle, (excepting in one case,) where it was only partially torn away, may be looked upon as the common result of the accident which produced these appearances; not so, however, with the tendons of the supra and infra-spinatus, and the teres minor muscles, from the greater tubercle, which appear to be more uncertain. In two instances all three tendons were torn away; in three cases only the tendon of the supra-spinatus; and in the remaining two cases, the whole of the tendons preserved their natural attachments.

"The capsular ligament appears in all cases to have been extensively lacerated at the upper part, and to have communicated with the bursa beneath the deltoid muscle, with only one exception, which hardly deserves to be excluded, from the very evident thickening, which implies that a communication had existed, but that union had afterwards taken place. In only two instances could any thing like a laceration be detected in the lower part of the capsule; and even in these it could only be suspected from the thickness of the capsule in this part. In all the cases the capacity of the general capsule was much increased, and included within it more of the upper part of the humerus than natural. In two cases it distinctly allowed the head of the bone to be displaced from the glenoid surface of the scapula without the least difficulty.

"The fibro-ligamentous bands must be considered as the result of the organization of fibrine thrown out during the inflammatory stage consequent upon the first effects of the injury. The enamel-like or porcelain secretion may probably be traced to a similar cause, or looked upon as one of the resources of nature, to prevent parts subjected to unusual friction from being materially injured by such a process. In all the cases, (excepting Case II) the joints presented more or less of the fibro-ligamentous bands, and the enamel-like secretion immediately decides the question, which might otherwise have arisen as to the probable date of the injuries.

"It is likely that the first case was an example of the effects that may be expected to follow the dislocation into the axilla, with the addition of a rupture from its origin of the round tendon of the biceps muscle, which, according to the opinion of Sir Astley Cooper, is by no means to be considered a common circumstance, or generally attendant on this accident. It would seem to have been produced by a severe blow on the top of the shoulder, from the appearance of injury and fracture of the humeral extremity of the clavicle.

"The second case is probably one showing the effects of partial dislocation, in which the head of the humerus is drawn forwards against the coracoid process of the scapula, but quickly slips back again into its natural socket. It is an example of a rupture of the round tendon of the biceps muscle, instead of the tendon being torn away from its origin.

"The third case, I am inclined to think, has been a dislocation into the axilla or on the dorsum of the scapula: it exhibited the most serious injuries; the whole of the tendons of the muscles were torn away from their attachments.

"The fourth and fifth cases occurred in the same individual. I am at a loss to say in what manner the bone had been forced to produce the appearances observed, but I am inclined to think it probable that they are both examples of the dislocation upwards. I find that Sir Astley Cooper says, in his valuable work on Dislocations, 'It has been supposed that a dislocation of the os humeri upwards might occur, but it is obvious it could only happen under fracture of the acromion: it is an accident I have never seen.' In strength of the opinion I venture to offer in these examples, I find that the humerus may be readily displaced upwards when the acromion is fractured; so that the head of the bone rests on the superior margin of the glenoid surface, but immediately returns to its natural situation.

"It has been suggested, that the accident might have happened from the individual falling down stairs while the arms were half extended, or by any violence that would tend to throw the head of the bone forcibly upwards. It is a remarkable fact, that the appearances in one shoulder-joint should be nearly a counterpart of the appearances in the other; they would seem to have been produced at the same time, and both to have been followed by severe inflammatory symptoms, as evinced by the fibro-ligamentous bands and the secretion of enamel on the processes of bone. The motion between the fractured ends of the acromion was considerable, and each surface is invested with a layer of cartilage.

"The sixth and seventh cases likewise occurred in the same subject. The appearances in the right shoulder, I think, clearly indicate that it is an example of the effects of a dislocation under the pectoral muscle. The appearances of the left shoulder result, perhaps, from a dislocation under the pectoral muscle, or into the axilla. The curious coincidence, that both the long tendons of the biceps muscle should have remained displaced, and that both should present the same remarkable character, are facts worthy of being remembered; and the question occurred to me, whether the pain and inconvenience a patient feels in some cases for a considerable time after the reduction of a dislocated arm, may not be owing to the long tendon of the biceps muscle having been displaced from its groove, which would not only give pain by stretching that muscle but very considerably affect the action of the forearm? In this case I should think it right to give the arm a gentle rotatory motion after reduction, that the parts might thereby be properly replaced and adjusted to their wonted situations."

Those readers who attended the Cleveland meeting will find in the paper just quoted much that they heard from the platform and saw on the screen. Even the little silvery fibers, described by Gilcreest as binding the displaced tendon of the biceps to the sides of its groove, are mentioned here. So, also, are discussed dislocations of the biceps tendon which Meyer has so many times observed. As for my own impression that I was the first to call attention to ruptures of the supraspinatus and of the other short rotators,—it has been gently but firmly and permanently removed.

To those who wish to go to the dissecting room and see these defects for themselves, so that they may use their own judgment in deciding whether attrition or trauma was the cause, I should like to offer the following suggestions:

1. Do not dissect off the deltoid and turn it up to expose the subacromial bursa, as does Meyer and as did Smith 100 years ago, but make the incision which I recommend for operative exploration by separating the deltoid fibers over the greater tuberosity and opening the roof of the bursa. Hold the lips of the incision apart, while the humerus is rotated to make the whole base of the bursa visible in the incision. You will find the sac much larger than it appears when the deltoid is removed or lifted, for this necessarily destroys the flexible periphery of the bursa. If there is a complete rupture of the supraspinatus, you will not have to incise the base, but will see the defect at once and, if it is a large one, you will see the cartilage of the joint through it.

2. Having done this, remove the deltoid and observe how insignificant the base of the bursa appears now that its periphery is lost.

3. Now cut across the muscle bellies of all the short rotators back of

the glenoid and pull the distal portions of the divided muscles outward until their tendinous portions—which I call the musculotendinous cuff—cling to the capsule so tightly that they cannot be readily separated from it.

4. Next, cut the capsule around the inferior three-fourths of the glenoid and look into the joint and observe the origin of the long head of the biceps on the glenoid rim. If the joint is normal, you will have the opportunity to observe the points shown in Figure 1.

In the normal joint the synovial membrane is reflected from the edge of the cartilage at a precise line; there is no exposed bone in the sulcus. The opening of the bicipital groove is also precise and the long biceps tendon fits it as a finger does a ring. The pillars of this ring are composed of fibers of the tendons of the supraspinatus (outer) and the subscapularis (inner) and the tendon cannot possibly dislocate until a considerable number of these fibers are evulsed from their attachments. The more fibers of the subscapularis that are torn, the more the tendon can slip over the corner of the lesser tuberosity in external rotation of the arm, but a complete dislocation of the tendon cannot occur unless all, or nearly all, of the insertion of the subscapularis is torn, for some of its fibers bridge the groove and unite with those of the supraspinatus.

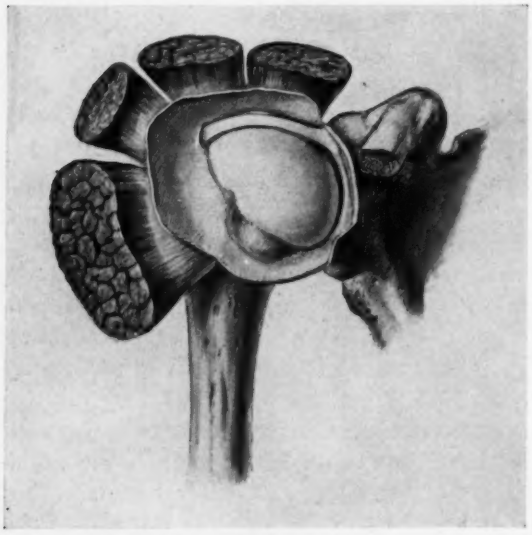

FIG. 1

Diagram showing the musculotendinous cuff. The inside of the joint is shown from the anterior aspect to indicate that there is no sulcus in the upper half of the anatomical neck and that in the lower half of the joint the insertion of the capsule is some distance from the articular rim. Here the bone is covered only by a thin layer of fibrous tissue and synovia.

The capsule has been cut just proximal to the line where it becomes welded into the musculotendinous cuff. In autopsy specimens one frequently finds bare bone between the attachment of the tendons and the articular cartilage, and such conditions are the end results of unrepaired ruptures of the tendon fibers. (*Reproduced from "The Shoulder" by the author.*)

Now, while all of this is true for a normal joint, it is difficult to find a perfectly normal one. Separation of some of the inner fibers of these tendons is the rule in most elderly subjects. Look for normal ones only in young cadavera. Even in these, as shown in Figure 2, you will usually find a few fibers evulsed. I speak of such lesions, where the nice reflection of the synovial membrane is torn away, as "rim rents", and I doubt if they ever heal in elderly tendons. I do not advocate operation on such lesions. I do advocate operation in cases of

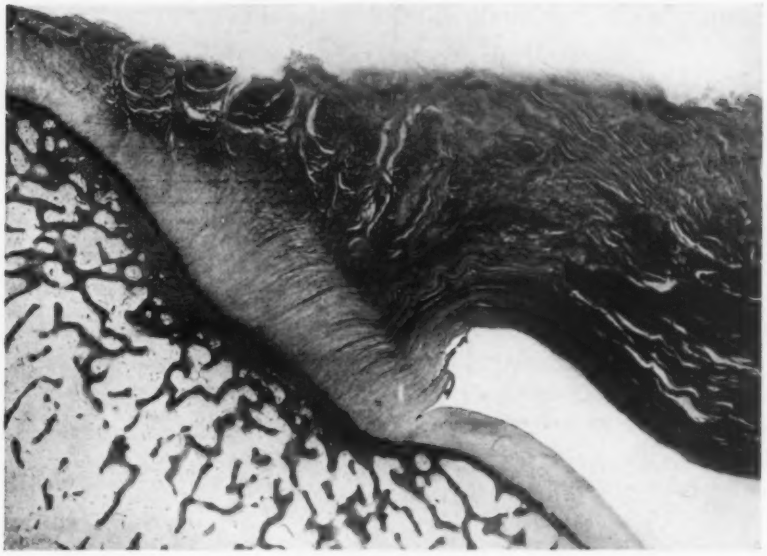

FIG. 2

Photomicrograph, showing normal insertion of the supraspinatus tendon. Notice that a few of the minor fibers are ruptured even in this case. In the cadavera of most elderly subjects a considerable number of fibers will be found to have ruptured. (*Reproduced from "The Shoulder" by the author.*)

complete rupture, where the defect is large enough to make a communication between the joint and the bursa. I agree with Philip Wilson when he says that whether or not these defects are traumatic, they can be repaired.

If any reader contemplates operating on shoulder lesions, I earnestly urge him to study the anatomy after this manner on a number of cadavera before he attempts operation on living patients. Then, at operation on living patients soon after injury, he will be able to recognize these lesions before great retraction has occurred and the falciform edge alluded to has formed.

There are many minor points in this brief, reprinted paper which show keen observation,—for instance, "the enamel-like or porcelain secretion" which I take to correspond to what I call eburnation of the facets, and is found on the tuberosity and beneath the acromion in most long-standing lesions. We seldom use the word "secretion" in such a connection today. Smith noted the existence of fibroligamentous bands, as well as many of the changes in the biceps tendon that Meyer describes. In one minor point his observations, I am inclined to think, are more accurate than those of any of our present-day writers,—*i.e.*, the relative frequency of ruptures in the subscapularis *versus* those in the supraspinatus. If partial ruptures are to be included, the subscapularis perhaps leads, but complete ruptures almost always include the supraspinatus, no matter which of the adjoining tendons are also involved. Ruptures of the

subscapularis are very rarely complete, I have never found one at operation and only one in a cadaver.

Smith must have been a very interesting character, with a truly scientific bent, if we may judge by the following footnote on "keeping a dissecting-room journal", which appeared as part of the article quoted:

> "We have been in the habit for some time past of keeping a dissecting-room journal, in which everything is entered that occurs out of the regular course, or differs from the natural appearance; the consequence has been that we have already collected a few interesting examples of varieties in the distribution of arteries and nerves, the absence of certain muscles, &c. If this plan were generally adopted in the dissecting-rooms in London, in the course of every session, a very curious and valuable collection might be made; the most interesting examples of which might be selected, and annually published in one of the medical periodicals."

One wonders if that journal has been continued by his successors. Perhaps we may account for the careful study which he made by his appreciation of the opportunity to study anatomical material secured by the exciting method alluded to in his first case.

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ROENTGENOGRAPHY OF TUBERCULOSIS OF THE JOINTS*

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It is common roentgenographic practice to produce films designed to show the bones only, the soft-tissue shadows being much too dark for intelligent study. Bone shadows are not particularly useful in *differential* diagnosis unless supplemented by soft-tissue shadows of effusion, swelling, infiltration, atrophy, relative density, etc., which are extremely useful. Changes in bone in most lesions come too late to really aid in the solution of the diagnostic problem. This leads to the erroneous conclusion that the roentgenogram is principally useful in showing the extent of the lesion and in confirming a clinical diagnosis which may have been made weeks or months previously.

Improvement in early differential diagnosis must start with the use of films which picture soft-tissue shadows properly. If the film fails to reveal clearly the fibrous texture of the subcutaneous tissues, the material is not the best for differential diagnosis in the extremities.

Assuming that films properly depict soft tissues as well as bone, what is the method of interpretation?

Lesions of the bones and joints may be classified almost at a glance as infections, tumors, calcareous degenerations, trophic lesions, or deformities. Infections involving bone reveal soft, hazy translucency about the bone lesion, due to increase of soft-tissue density within the bone, or they present subperiosteal calcifications of irregular texture and density which may hide the increase of soft-tissue density. When the bone is not visibly involved, the distribution, character, and outline of effusion and swelling are characteristic and the features of the other classes of lesions are absent. In tuberculosis, effusions and soft-tissue abscesses tend to be as dense as adjacent muscle shadows, sharply outlined, and centered on the lesion or elongated in the planes of the involved tissue.

The differentiation of tuberculosis from other infections is a matter of perceiving the characteristic expression of chronic and progressive development of effusion, soft-tissue atrophy, decalcification, and thinning of the cartilage space without productive calcifying reaction. One must see that these features are present in the degree and in the relation to each other which express the tendency to their chronic and progressive development. When this picture is evident, the lesion is probably tuberculous, but, before that diagnosis is made, it is necessary to consider the circumstances under which the lesion has developed. This is the only way to identify other infections which may imitate the picture of tuberculosis, or

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 14, 1937.

FIG. 1

tuberculous lesions which may simulate other infections.

For example, a gonococcic lesion may imitate tuberculous arthritis. We will consider only a single feature of such a lesion,—the effusion. In gonococcic arthritis, effusion reaches the maximum within the first month and subsides in a few more weeks. Corresponding degrees of effusion occur in tuberculosis, but the duration is much longer,—twenty or thirty times as long. We have only to inquire as to the duration of the lesion to determine whether the amount of effusion present indicates tuberculous or gonococcic infection. This is consideration of the *circumstances* of the lesion. The duration of the disease has been used to indicate the proper choice of two possible interpretations of a given shadow.

The final diagnostic step is not concerned with the question, "Is this the picture of tuberculosis?" but with the question, "Is this the picture which tuberculosis would have produced in this particular patient under the particular circumstances of the lesion?"

Among the circumstances of the lesion which are important in the diagnosis of tuberculosis and which should, therefore, be known before attempting that diagnosis in a given case are:

1. The duration, which affects the amount of effusion, atrophy, decalcification, and thinning of the joint space particularly.

2. The previous treatment. Immobilization limits or reduces effusion and increases atrophy. Aspiration reduces effusion. Surgical procedures may alter the picture in various ways.

3. The age of the patient. Decalcification tends to be more prominent and more marked in children than in adults, but it may appear more quickly in the latter.

4. The virulence of the lesion. If the patient is not greatly affected by the lesion, atrophy and decalcification are less than when the functioning of the limb has been very much affected.

5. The presence of sinuses which may allow the development of secondary infection and the superimposing of pyogenic features on the tuberculous picture.

These are the more important circumstances of the lesion, consideration of which ordinarily serves to answer the question of diagnosis, but the more difficult the diagnostic problem the more necessary it becomes to know even more fully all of the circumstances of the case.

The illustrations indicate the similarity that may exist between tuberculosis and other diseases.

FIG. 2

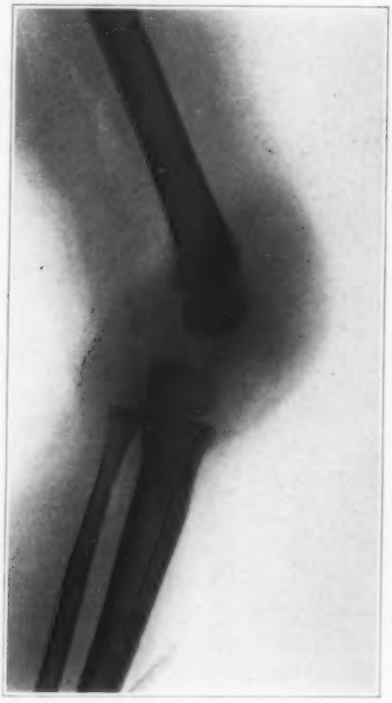

FIG. 3

In Figures 1, 2, and 3, each lesion presents a marked effusion without bone destruction or calcareous productive reaction,—a superficially similar picture. The illustrations are presented merely to emphasize this similarity. The differences cannot be truly reproduced in prints, but were detectable in the roentgenogram, on comparison with the opposite knee, as follows:

Figure 1 shows tuberculosis of six months' duration in a male, aged five. The effusion is dense and sharply outlined. There is no swelling beyond the capsule. The patella and epiphyses are overdeveloped. The cartilaginous joint space has not yet become thin. There is slight general decalcification. Soft-tissue atrophy is marked. The strongest suggestion that this lesion is tuberculous originates from the prominence of soft-tissue atrophy in proportion to the other changes in an untreated arthritis of six months' duration.

Figure 2 depicts rheumatoid arthritis of two and one-half years' duration in a female, aged eight. In spite of the long duration and the occasional fixation in plaster, there is no decalcification, the cartilaginous joint space is not thin, and soft-tissue atrophy is slight. In view of the circumstances, the lesion fails to express a tendency to chronic and progressive development of soft-tissue atrophy, decalcification, and thinning of the cartilaginous joint space. Tuberculous arthritis rarely exists as

FIG. 4

long as one year without thinning the joint space.

Figure 3 shows pyogenic arthritis, one month after onset, in a male, aged three. The joint was opened and drained for three days in the first week of the disease. The effusion is not so sharply defined because of the presence of slight swelling and infiltration, extending to the subcutaneous tissues. This represents a more active and acute process than tuberculosis and, consistent therewith, there is no atrophy and no decalcification as yet. The cartilaginous joint space has not yet become thin.

Figure 4 presents a picture such as might be simulated by subsided tuberculous arthritis. Actually, it is subsiding gonococcic arthritis of five months' duration in a male, aged thirty-nine. The time is too short for tuberculosis to arrive at this state. Persistence of marked local decalcification, particularly notable in the patella, indicates that there recently has been marked disturbance and hence the lesion has subsided rapidly.

There is no formula for the roentgenographic diagnosis of bone and joint tuberculosis. When there is a diagnostic problem to be solved, it is necessary to consider the prominence and relation of the various roentgenographic features to each other and to the circumstances of the case. While it is true that the expert may deduce the circumstances and history of the case from the roentgenogram with considerable accuracy, that ability is acquired only by a long period of study of the relation of the various pictures to the known circumstances. The simple way is to make available to the interpreter the facts which may have an influence on the degree of development of any of the various shadows present. Only when the interpreter has these facts and applies them properly to the films demonstrating the soft tissues will the diagnosis of bone and joint lesions reach full efficiency.

THE PRINCIPLES OF ORTHOPAEDIC AND SURGICAL TREATMENT IN THE RHEUMATOID TYPE OF ARTHRITIS *

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The problem of treatment of arthritis has been revolutionized in recent years by a more general recognition of the fact that it is one that demands a coordinated attack by members of a team and, particularly, the closest cooperation between physician and orthopaedic surgeon. Such teamwork can best be achieved in special Arthritic Units such as certain admirable ones in America, and in England that under the aegis of the London County Council at St. Stephen's Hospital, which works in cooperation with the St. John Clinic and Institute. The need for similar Arthritic Units in other large centers of population is urgent.

This problem is simplified by its consideration under:

1. The pre-arthritic stage;
2. The arthritic stage.

PRE-ARTHRITIC STAGE

Defective posture is, as Swaim and others have urged, an important predisposing cause of arthritis and may act in two principal ways. Let us take in the first place the common syndrome of round shoulders (kyphosis), exaggerated lumbar curve (lordosis), prominent abdomen, knock-knee (genu valgum), and pronated foot (pes planus). In such an individual the ribs are crowded together and the subcostal angle is acute. The diaphragm and chest wall function at marked mechanical disadvantage, with consequent interference with the normal function of the heart and lungs, and there is grave interference with the function of the abdominal organs, owing to the associated visceral prolapse. The effect upon the general circulation is serious and it is, therefore, not surprising that, in such cases of pronounced postural defects, the circulation of the extremities is impaired, causing the soil to be prepared for the onset of the arthritic seed. Secondly, it is commonly found, particularly in the spine and in the lower extremity, that arthritis supervenes in joints which have been subjected to undue strain for many years, owing to the presence of deformities due to defective posture.

There can be little doubt that the welcome interest that is now being shown by the authorities in many countries in the problem of insuring and maintaining the highest degree of physical fitness in all classes of the com-

* A lecture delivered at the St. John Clinic and Institute of Physical Medicine, London, England, March 19, 1937.

munity will bear a rich harvest and may well lead to a lowering of the incidence rate of many forms of rheumatic disease. It is to be hoped that the need for physical education will be brought home, not only to the youth of the nations, but to those who are no longer young. Many of the breakdowns of middle age, including doubtless many cases of arthritis, are due to a lack of observance of even the most elementary principles of physical well-being. It is, therefore, clear that the orthopaedic surgeon has an important rôle in schemes of physical training and in the prevention of many conditions which are predisposing causes of arthritis.

ARTHRITIC STAGE

Until comparatively recent years, a quite unjustifiable atmosphere of pessimism surrounded the treatment of arthritis. This attitude was reflected in half-hearted attempts to improve the lot of the arthritic patient, or even in a policy of *laisser faire*. Such patients were not regarded as "interesting cases", with consequences that were a reproach to Medicine. Although such patients are still often looked upon with disfavor at the large teaching hospitals, the excellent results that are now being achieved at special Arthritic Centers by the small band of enthusiasts who do in fact find arthritic patients "interesting" are at last bringing home to the profession the great possibilities of modern therapy in this vital branch of Medicine.

The orthopaedic and surgical treatment of the rheumatoid type of arthritis will be considered under two principal headings:

1. Prevention and treatment of deformity in the earlier and more acute stages.
2. Orthopaedic and surgical treatment in the later and more chronic stages.

PREVENTION AND TREATMENT OF DEFORMITY IN THE EARLIER AND MORE ACUTE STAGES

The deformities that occur in this stage are at first due to muscle spasm. It is usually found that flexion is a prominent feature because the more powerful flexors overcome their antagonists and because the patient often finds flexion of the affected joint to be the position of greatest comfort. In other joints, such as the shoulder and the hip, other deformities, such as abduction, adduction, or rotation, are combined with flexion, owing to spasm of particular muscle groups. In such early stages, if muscle spasm can be inhibited, the deformities can be corrected with comparative ease. After a fairly short period, however, these deformities, at first due to spasm, become "fixed", owing to actual shortening of the joint capsule and periarticular structures on the side of maximum contracture, and, in neglected cases, actual adhesion between the articular surfaces may occur by fibrous tissue or even by bone. The principles of treatment of the earlier stages may therefore be enumerated as follows:

1. In the acute stages, when muscle spasm is prominent, every ef-

fort should be made to prevent deformity; if necessary, light, easily removable splints may be used.

2. Our ultimate aim should be, wherever possible, to preserve a movable and functionally useful joint. However, the possibility of ankylosis is always present, so that the affected joint should be maintained in the "*optimum position*", if necessary in some form of light and comfortable apparatus which can be easily removed for local physical treatment.

3. When muscle spasm has already brought about deformed positions of the joints, these must be corrected at the earliest possible moment and before the deformities have become fixed. Table I shows the deformity which the untreated joint tends to assume and the corresponding optimum position.

TABLE I

CHARACTERISTIC TYPES OF DEFORMITY COMPARED WITH POSITIONS OF ELECTION FOR ANKYLOSIS (SPINE NOT INCLUDED)

Deformity	Position of Election for Ankylosis
Hand: Ulnar deflection of fingers at metacarpophalangeal joints. Well-marked flexion at interphalangeal joints; sometimes hyperextension at proximal interphalangeal joints.	Moderate degree of flexion at metacarpophalangeal and interphalangeal joints. Absence of lateral deviation.
Wrist: Flexion.	Extension through 45 degrees.
Elbow: Usually midway between flexion and extension; forearm in pronation.	Varies according to occupation and patient's wishes. Probably slightly less than 90 degrees is best. Forearm midway between pronation and supination.
Shoulder: Flexed, adducted, and rotated inward.	Slight flexion; abduction through 45 degrees (adults) or 70 degrees (children).
Foot: Hallux valgus or hallux rigidus. Toes deviated outward at metatarsophalangeal joints. Pronation at midtarsal joint, with consequent flat-foot.	The normal position. Slight inversion is sometimes advantageous.
Ankle: Plantar-flexed.	Foot forms an angle of 90 degrees with leg. A few degrees of dorsiflexion is sometimes preferable.
Knee: Flexed. In severe cases the tibia is subluxated backward and rotated outward.	Complete extension, although, if ankylosis is bony, a few degrees of flexion may be of advantage.
Hip: Flexed, adducted, and rotated inward (late stages).	Slight abduction and rotation outward in extension.

In recumbent cases, every effort must be made to avoid faulty posture. Many a neglected case is seen in which a prominent kyphosis has developed because the patient has been propped up with pillows. The hips and knees are frequently fixed in flexion, owing to the bad practice of placing a pillow under the knees, and the pressure of the bedclothes often causes the feet to be fixed in plantar flexion combined with valgus deformity.

Plaster-of-Paris

Various methods of splintage have been devised for the prevention of deformity and for its correction when due to muscle spasm. Some surgeons pin their faith upon plaster-of-Paris. This method requires extreme care in its application and it is of the utmost importance that, if plaster is used, the splint should be bivalved soon after its application, so that no undue pressure is caused and the joint is made accessible for physical treatment and gentle assisted movements.

No condemnation is too strong for the practice of immobilizing the affected joint in plaster for a long period, and no method is more likely to bring about irremediable ankylosis. Space will not permit a detailed description of the plaster-of-Paris technique, and those interested should consult the writings of Kindersley, Swaim, and others. The principles of the method can, however, be quite simply stated. Let us assume, for example, that we are dealing with the flexed arthritic knee. A plaster is first applied to the flexed and painful knee and bivalved laterally after a few days, so that the segments can be removed for effleurage, or heat therapy, or other forms of physical treatment. After a short period of rest in this position, it is usually found that spasm is so far diminished that a second plaster can be applied in an improved position. This process is repeated until the position of deformity is completely rectified.

Splints

The author has devised splints for both upper and lower extremities, which, in his opinion, banish many of the disadvantages of plaster. It is admitted that the splints involve a greater initial outlay than does plaster technique, but they have the advantages that they can be used repeatedly, they are simpler and more rapid in their application or reapplication, and there is less risk of interference with the circulation of the limb.

The "Universal" splint for the joints of the upper extremity is constructed of duralumin and is fitted with special types of universal joints at shoulder and elbow, which permit the shoulder or elbow to be fixed in any desired position. At the shoulder, for example, abduction, adduction, flexion, extension, and rotation can be altered as desired. Extension is possible in both arm and forearm pieces by extension slides. As constructed, the splint is applicable for arthritis affecting all the joints of the upper extremity, but the lower sections can be removed if necessary for application to the elbow or wrist.

The "Universal" splint for the lower extremity is constructed on somewhat similar principles and has been found valuable in the treatment of arthritis of the knee and ankle. An important feature is that the degree of flexion and extension at both knee and ankle and of abduction and adduction of the foot can be accurately adjusted.

Weight Extension

This is an alternative method and is sometimes of value, particularly in the case of the arthritic hip and when pain and spasm are marked. It is a method which requires close personal supervision by the orthopaedic surgeon and it should be remembered that, unless applied in accordance with correct mechanical principles, it may cause increased pain and muscle spasm. In the hip, for example, extension must be applied in the line of the thigh. If the weight extension is applied in the wrong axis, interosseous pressure at the hip is increased, causing increased spasm of the psoas and iliacus and often the development of lordosis.

Similar principles of deformity prevention are applicable to patients suffering from spondylitis ankylopoietica. In this disease, the need for prevention of deformity or for its correction in the earliest possible stages is most urgent. There is no more tragic sight than an exaggerated kyphosis which has been fixed either by very dense adhesions or by a bridge of bone connecting the vertebrae. Deformity can be prevented in these cases, and in the early stages it can be corrected by the application of the principle of extension in dorsal recumbency, either in a plaster bed or on a special mattress or Bradford frame. The normal forward convexity of the lumbar spine must be remembered and undue flattening guarded against.

ORTHOPAEDIC AND SURGICAL TREATMENT IN THE LATE AND MORE CHRONIC STAGES

Of the patients who, from the first, have had a more chronic type, many will be ambulatory, except when deformity or pain is very marked. Large numbers of such patients attend the St. John Clinic and Institute of Physical Medicine and the various forms of physical and medical treatment adopted have already been described in the series of lectures of which this is a part. In the treatment of these patients, close cooperation exists between the different departments, and its value can hardly be overestimated. Benefit is often obtained by employing in turn the various methods of physical treatment, and coordination between the medical and orthopaedic departments is of vital importance. Most of the methods of physical treatment—such as heat in its various applications, electricity, ultra-violet or balneological therapy—achieve their purpose best when combined with movements, especially in the form of carefully graduated exercises to strengthen the weakened musculature and to restore movement to the joints stiffened by the disease. In some cases, orthopaedic apparatus may be necessary, but, as far as possible, such methods are

avoided and indeed are often rendered unnecessary by modern treatment.

If undue mobility of a joint has been caused by destructive changes in the articular surface, as in the knee, some form of walking calliper splint may be necessary. The so-called "destressing" splints for arthritis of the knee or hip are, in the author's experience, of doubtful value.

The Use of Apparatus in Ambulatory Cases

In certain cases of arthritis, particularly in the weight-bearing joints such as the hip or knee, and when pain on exercise is a prominent feature, an attempt may be made to relieve intra-osseous pressure by some form of "destressing" apparatus to enable the patient to take exercise. Most of this apparatus is constructed after the pattern of the Thomas splint. In applying extension to the hip or knee, the principal *point d'appui* above should be the ischial tuberosity. The lateral steel supports are made a little longer than the limb and terminate in right-angled pieces that fit into the heel of the patient's shoe. The patient's heel is separated by a short space from the inner surface of the heel of the shoe, so that, in standing or walking, extension of the limb and separation of the sensitive joint surfaces are brought about. A locking device can be introduced at the level of the knee joint to enable the patient to sit in comfort.

Is it mechanically possible, however, to separate the joint surfaces in this way in an ambulatory form of apparatus, and, even if it is possible, is not any such attempt based upon an erroneous conception of the cause of the pain in these cases?

Treatment of Deformity in the Later Stages of the Rheumatoid Type of Arthritis by Manipulation

The treatment of these deformities by manipulation is, in suitable cases, of great value. Success in this highly specialized branch of orthopaedic work necessitates a long period of training, without which its use is fraught with great difficulties and even dangers. The unqualified condemnation which this method of treatment formerly received in textbooks on Medicine is, however, unjustifiable when the "forced movements" to which they refer are replaced by gentleness and skill. Textbooks wisely warn their readers about the violent reaction in the joint and the shock that may follow the use of undue force in performing manipulation, but both of these untoward results are extremely rare in the experience of those who have specialized in manipulative work. Manipulation of a stiffened arthritic joint should never be performed when any signs of active disease are present either in the stiffened joint or in other regions. If there is any doubt upon this point, the sedimentation rate should always be ascertained. Roentgenographic examination is a necessary preliminary, as cases showing marked destruction of the articular surfaces or dense intra-articular ankylosis, either fibrous or bony, are obviously unsuitable. Joints with minor degrees of stiffness often improve markedly

with various methods of physical treatment. The latter should in such cases, therefore, be given a fair trial, and only in the event of their failure should manipulation be considered. It should be remembered, however, that a suitably performed manipulation may obviate long periods of physical treatment and may thus save much time and energy and relieve the strain upon departments of physiotherapy.

The stretching or breaking down of adhesions is of necessity a painful process, and an anaesthetic should always be administered. Occasionally, slight cases of adhesions can be manipulated under local anaesthesia or gas in the out-patient department or consulting-room. In most cases, however, it is more satisfactory to admit the patient to a hospital or a nursing home, so that proper preparation can be carried out and a general anaesthetic given. Sodium evipan, given intravenously, is a valuable anaesthetic for cases of slight or of moderate degree.

One of the most important factors of success in manipulative work consists in a policy of gradually restoring movement by a carefully planned series of manipulations. In this way, reaction in the manipulated joint can usually be completely avoided. In straightening a flexed knee, for example, the limb is temporarily fixed after manipulation in some easily removable splint in the improved position attained by the first manipulation. The splint is removed daily for physical treatment, including active movements. After a week, or possibly a little longer, a further manipulation is performed and the splint is reapplied at the altered angle. This process is repeated until complete extension is restored. Similar measures are adopted for increasing the flexion of the knee, should this be restricted, or for increasing the range of movement of other joints.

As previously mentioned, plaster casts may be used instead of splints, provided the casts are bivalved at the earliest possible moment to allow access to the limb for treatment. The greatest care must always be taken to avoid undue force in performing any manipulation, especially in a case of arthritis, for it must be remembered that in these cases the bone is often atrophic and liable to fracture.

RHEUMATOID ARTHRITIS OF THE WRIST JOINT

The orthopaedic aspects of the treatment of the rheumatoid type of arthritis which have been described may now be briefly summarized by applying them to the treatment of various degrees of the rheumatoid type of arthritis of the wrist joint.

Early Stages

The tendency to drop-wrist, owing to the more powerful action of the flexors of the wrist, must be borne in mind. This may sometimes be prevented, when spasm is not a prominent feature, by gentle daily movements, both active and assisted, but, if spasm is pronounced, a light cock-up splint should be worn, which, if necessary, can be so adjusted as to

keep the thumb and fingers extended. This splint should be removed daily for gentle movements, as fingers that have become fixed in extension are even more useless than those that are partially flexed.

The author prefers a light, well-fitting, and easily removable metal cock-up splint for this purpose. If plaster is used, the splint should be bivalved within twenty-four hours, so that sections can be removed daily for the necessary movements of the wrist and the fingers. As the acute symptoms subside, the splint can be discarded for a few hours daily and later it may be discontinued during the day but worn at night before being discarded altogether. In an acute case, if drop-wrist due to muscle spasm has already occurred, this deformity must be gently overcome before the cock-up splint is applied. When painful spasm is very marked, an anaesthetic may be necessary.

Chronic Type

The treatment of a more chronic variety of the rheumatoid type of arthritis of the wrist joint will now be discussed. No actual deformity is present, but the movements of the joint are restricted by 25 per cent., and a fair trial of various forms of physical treatment has been made. In such a case, manipulation under some such anaesthetic as gas and oxygen or intravenous sodium evipan is indicated. No form of retention splint is necessary, and active and passive movements are commenced immediately and maintained regularly.

Neglected Case

We will now discuss the treatment of a neglected case of the same type of arthritis in which drop-wrist of the "fixed" type has developed. In such a case, a series of manipulations at intervals under anaesthesia is indicated. The actual number of manipulations will depend upon the degree of stiffness, and preliminary roentgenography is always necessary to ascertain the state of the articular surfaces. At the first manipulation, it may be advisable to rest content with gaining 25 degrees of extension. A palmar splint is applied, which maintains the wrist in the corrected position, but the splint should be removed within twenty-four hours for active and passive movements, preceded by radiant heat or infra-red treatment. At the end of a week or ten days, it will probably be found that the patient is able to extend the wrist through the increased range, and a second manipulation may be performed and the power of extension of the wrist still further improved. The palmar splint is adjusted accordingly and the after-treatment continued as before, and in a short time the power of complete active extension at the wrist joint is obtained. The palmar splint is then adjusted in such a way that the wrist is kept fully extended. It should be worn both day and night at first and then left off for gradually increasing intervals during the day and finally discarded altogether. Similar principles are applicable to the orthopaedic treatment of other joints.

SURGICAL OPERATIONS IN ARTHRITIS OF THE RHEUMATOID TYPE

There can be little doubt that, with a more general recognition and observance of the principles of physical and orthopaedic treatment in the earlier stages of arthritis, and with closer cooperation between medical and orthopaedic departments, the number of advanced cases of deformity, for which surgical operation is required, will steadily diminish. Until this ideal state of affairs has been established, however, such operations will continue to play a valuable and important rôle in the treatment of carefully selected cases of arthritis, particularly in the later stages. Surgical operations in arthritis may be divided into those which aim at fixation or ankylosis of the affected joint and those which endeavor to retain a movable joint. As a general rule, in cases of advanced arthritis, ankylosis in the optimum position is aimed at in the weight-bearing joints of the lower extremity where stability is a principal consideration.

Excision of an arthritic joint is indicated when pain is severe and resists other measures and is associated with marked destruction of the articular surfaces. In the case of the knee, after removal of the articular surfaces, ankylosis in the optimum position is deliberately sought, but, in the cases of the hip, the shoulder, the elbow, and the metatarsophalangeal joint of the great toe, the ultimate aim is usually a movable joint.

Arthrodesis aims at the production of ankylosis in a joint and is most often performed upon the hip joint when pain is intolerable and resists other measures. When it is satisfactorily performed and bony union is secured, relief from pain in the affected hip is obtained. The operation is a severe one and it is often contra-indicated by the age and general condition of the arthritic patient. This operation should never be performed without a previous thorough and patient trial of modern methods of physiotherapy and particularly of manipulative treatment.

Osteotomy is necessary when osseous ankylosis has occurred in a bad position. This operation is valuable in cases of ankylosis of the shoulder or hip in marked adduction.

Arthroplasty is an operation that is at present on trial in the treatment of arthritis. With further study and technical improvement, it may prove to be of great value. The indications for its performance are cases of bilateral ankylosis, such as stiffness of both hips, elbows, or knees, or combinations of ankylosed hips and knees.

Posterior capsulotomy is of value in cases of obstinate flexion deformity of the knee, which have proved resistant to manipulation, in which the roentgenogram shows slight or moderate changes in the articular surfaces, and in which it is clear that the obstruction to extension is due to contracture of the posterior portion of the capsule of the knee joint.

Synovectomy is a valuable operative procedure in suitable cases. It is particularly indicated in cases of the rheumatoid type of arthritis of the knee joint, in which the disease affects principally the synovial membrane and in which can be palpated enlarged and tender synovial villi which, by

becoming squeezed between the articular surfaces, give rise to recurrent attacks of pain and effusion.

Removal of loose bodies is sometimes necessary. In the later stages of the rheumatoid type, secondary osteo-arthritic changes may supervene, with formation of osteophytes. Occasionally such osteophytes may become detached and give rise to recurrent attacks of locking, necessitating their removal.

Arthrotomy and lavage is a method which, in the author's experience, has proved valuable in subacute arthritis of the rheumatoid type. It has proved of greatest value in the case of arthritis of the knee, mainly involving the synovial membrane, which has proved resistant to other methods of treatment. A small incision is made upon the inner side of the knee, any enlarged synovial fringes in the vicinity are removed, and the joint is thoroughly irrigated with Dakin's solution. In many cases, the symptoms clear up in a remarkable manner, and the improvement is permanent.

CONCLUSIONS

In conclusion, it may be stated that the great advances that have been made in recent years in the treatment of arthritis by physical, orthopaedic, and surgical measures and the equally important advances in the purely medical treatment have revolutionized our outlook upon this scourge of mankind and justify us in replacing the former pessimistic attitude by one of guarded optimism.

JOINT CHANGES RESULTING FROM PATELLAR DISPLACEMENT AND THEIR RELATION TO DEGENERATIVE JOINT DISEASE * †

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In a previous investigation [6] concerning the repair of articular cartilage in the knee joints of dogs, marked intra-articular changes similar to those of degenerative joint disease [2] ‡ were observed in all joints in which the patella had become permanently displaced. (See Figures 1, 2, 3, 4, 5, and 6.) Since similarly operated joints in which the anatomical relations of the patella to other joint structures were maintained showed no important intra-articular changes, we concluded that the observed degenerative and hypertrophic changes in the articular cartilage had resulted because of the patellar displacement.

The present study was undertaken to determine the effects of patellar displacement in knee joints which had not been opened surgically or traumatized in any other manner, and to compare the changes produced with those found in human knee joints with displaced patellae.

FIG. 1

Roentgenogram of the right knee joint of a dog in which the patella had become displaced twelve weeks earlier. The joint was enlarged, marginal proliferation had taken place, and numerous joint mice had formed. Note the position of the patella in relation to the femoral condyle.

METHODS

Owing to the difficulties encountered in maintaining patellar displacement in the unopened knee joints of dogs, it was found necessary to carry out the present study on rabbits.

Operation: Under ether anaesthesia and with sterile surgical technique, a small incision was made just medial to the infrapatellar ligament of one knee joint. The superficial fascia was divided

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‡ The synonyms commonly employed are hypertrophic arthritis, osteo-arthritis, and degenerative arthritis.

FIG. 2

Gross specimen (× 2). Marked marginal lipping of the femoral articular surface had taken place in this dog joint after the patella had been displaced for a period of twelve weeks. (*Courtesy of the American Journal of Pathology.*)

and reflected, so as to expose the patellar and internal lateral ligaments. A chromic catgut suture (No. 1) was then inserted through the middle portion of the patellar ligament. Traction upon this suture lifted the patella forward, so that it could be easily dislocated to the inner side of the medial ridge of the patellar surface of the femur. To insure permanent displacement, the suture was then passed through the internal lateral ligament

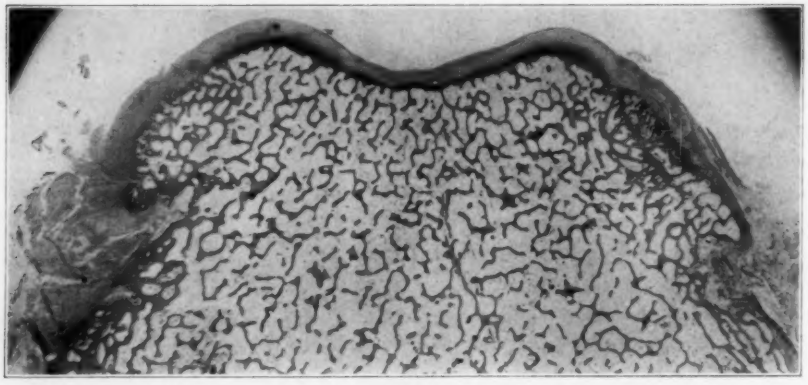

FIG. 3

A very low-powered photomicrograph (× 5) of a complete transverse section through the patellar surface of a dog joint in which patellar displacement had existed for a period of twenty weeks. Note the marginal lipping which has developed at the line of union of the synovial membrane and the perichondrium. One can readily see that the point of capsular attachment to bone corresponds with the areas of greatest overgrowth.

and tied. The fascia and skin were closed in layers with sutures of silk and a collodion dressing was applied. The opposite knee joint served as the control. Eleven animals were so treated.

Postoperatively each animal was confined to a cage, no attempt being made to restrict motion in the operated joint. Slight swelling at the operative site, an obvious limp, and limitation of motion persisted for from two to five days. Following this, the animals hopped about in a normal manner, although two of them continued to exhibit moderate limitation of motion. A few weeks later, in each case the operated joint was found to be wider than its control and the lateral articular margins felt irregular on palpation.

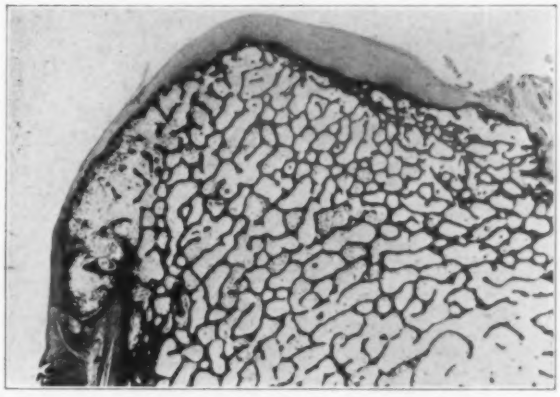

FIG. 4

Photomicrograph (× 5). Pronounced proliferative changes had taken place at the point of capsular attachment to the articular margin in this dog joint after a four-week period of patellar displacement.

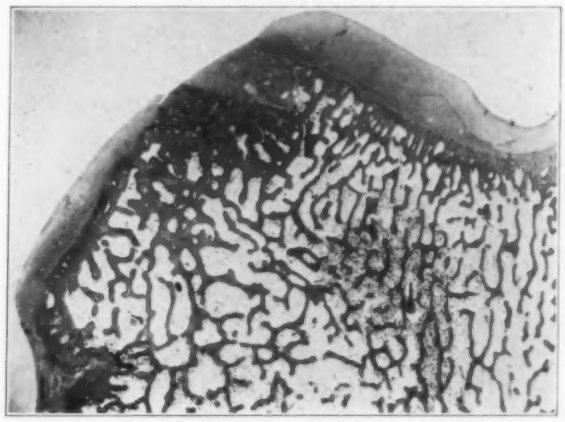

FIG. 5

A low-power photomicrograph (× 5) of the femoral articular surface of a dog joint, showing an area from which the articular cartilage had been worn away by the displaced patella. Marked condensation and polishing (eburnation) of the exposed subchondral bone had taken place. Below this point may be seen marginal overgrowth (lipping) where the synovial membrane of the joint capsule is reflected onto the articular margin. Patellar displacement had existed for twelve weeks.

The animals were sacrificed under ether anaesthesia at intervals of four, eight, twelve, and twenty-eight weeks following patellar displacement. The knee joints from each rabbit were removed, partially opened, and immersed in a 10-per-cent. solution of formaldehyde. After thorough fixation, they were completely opened, examined, and photographed. Blocks of tissue were removed from representative areas of each joint. The soft tissues were embedded in paraffin. The tissue blocks containing bone were decalcified in a 5-per-cent. solution of nitric acid and em-

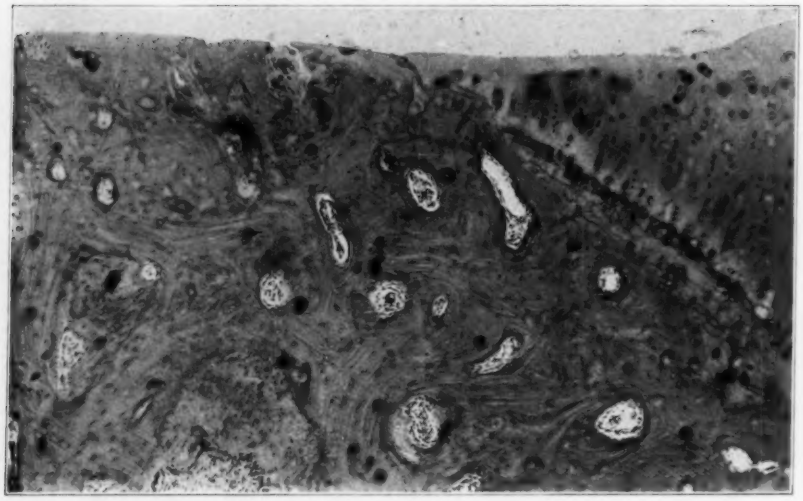

FIG. 6

Photomicrograph (× 64), showing an area of eburnation from the joint illustrated in Fig. 5. Note the endosteal activity which has resulted in the condensation of the subchondral bone.

bedded in celloidin. All microscopic sections were stained with hematoxylin and eosin.

MACROSCOPIC APPEARANCE OF THE JOINTS

All joints with displaced patellae were irregular in contour and wider (twenty-two to thirty millimeters) than their controls (nineteen to twenty millimeters). The average increase in width for the total series was five and four-tenths millimeters. There was no increase in synovial-fluid content. The chief intra-articular changes noted were degeneration of the articular-cartilage surfaces and hypertrophy of the articular margins.

Figure 7 illustrates the intra-articular changes which ensue following patellar displacement of four weeks' duration. There may be noted a newly formed patellar groove medial to the inner patellar ridge, slight elevation of the lateral articular margin, and marked atrophy of the articular cartilage of the patellar groove of the femur. The latter was so marked over the epicondylar ridge that the underlying red subchondral bone was readily seen. The articular cartilage of the patella showed no gross changes. The synovial membrane appeared slightly thickened with beginning villus formation. The joint was six millimeters wider than its control. The increased width appeared to have resulted from proliferation of the synovial membrane, the perichondrium, and the underlying bone on the medial side of the femoral condyle at the point where the synovial membrane is attached, thus providing a new articular surface for the displaced patella.

More marked marginal proliferation of the articular cartilage of both patellar ridges was observed after eight weeks of patellar displacement.

In addition, depressed areas, from which the cartilage had almost completely disappeared, were seen on the articulating surface of the femur. The displaced patella rested in a recently formed groove (similar to that shown in Figure 7) consisting of newly formed cartilage and underlying bone. This new patellar groove accounted for the five-millimeter increase in width of the femur. Although the articular surface of the patella appeared normal, the synovial membrane about it was slightly hypertrophied.

The intra-articular changes resulting from twelve weeks' patellar displacement were similar to those previously mentioned. In one instance the patella was only slightly displaced, resting on the inner side of the medial femoral condyle. The constant movement of the patella over this area resulted in complete disappearance of the femoral articular cartilage in two places, measuring approximately two by three millimeters. Moderate marginal lipping of the lateral femoral condyle had occurred. In another joint in which the patella had been completely displaced for this same period of time, the observed changes were much more marked. (See Figure 8.) The femur was ten millimeters wider than its control. The large, recently formed patellar groove was covered in its deepest portion by irregular, pitted, frayed cartilage. The original femoral articulating surface was dull and roughened in appearance. The elevated nodular condyles were very similar to those seen in the degenerative joint disease of the human. The patella was partly obscured by surrounding hypertrophied villi. The changes in the synovial membrane were more marked in this joint than in any other in the series. The patellar cartilage was undergoing degenerative

FIG. 7

Photograph (natural size) of the left and right knee joints of a rabbit, with patellar displacement of four weeks' duration in the left joint. Note the atrophy of cartilage on the femoral articular surface and the newly formed patellar groove on the medial femoral condyle.

FIG. 8

Photograph (natural size) of the right and left knee joints of a rabbit in which the patella of the left joint had been displaced twelve weeks earlier. The joint is markedly widened. The articular margins of the femur are elevated and overhanging. Two joint mice had formed and there was moderate hypertrophy of the synovial membrane.

changes as shown by its dull, pitted, uneven surface. Two small round joint mice, measuring four by three millimeters by one millimeter and one and five-tenths millimeters by one by one millimeter, were found in the quadriceps pouch.

The alterations in the knee joint after twenty-eight weeks of patellar displacement (Fig. 9) were not unlike those just described, except that the synovial membrane showed less evidence of hypertrophy.

Upon sacrificing one animal with supposed displacement of the patella of twenty weeks' duration and two animals with displacement of twelve weeks' duration, no intra-articular changes were noted and the patellae were found in their normal positions. These findings indicated that the sutures had not held, thus allowing the patellae to return to their normal positions soon after displacement. The absence of intra-articular changes in these and the control joints would seem ample evidence that the previously described degenerative and hypertrophic changes resulted solely from the displacement of the patella and the intra-articular derangements which follow.

MICROSCOPIC EXAMINATION OF THE JOINTS

The chief changes noted in the sections from these joints were those of degeneration of articular cartilage, proliferation of the tissues at the perichondrial margins of the articulating surfaces, and slight to moderate proliferative changes in the synovial membrane. These changes as observed in the dogs are readily seen in Figures 3 and 5. The changes encountered in the rabbits are well illustrated in Figures 11, 12, and 13 and

should be compared with the normal (Fig. 10).

The most marked intra-articular changes following four weeks of patellar displacement were observed in the articular end of the femur (Figs. 7 and 11). The cartilage over the medial condyle was much thinner than normal. In other areas, there was noted fibrillation or superficial depressions and pitting, in which multiplication of cartilage cells had taken place. Marked reconstruction of the femoral condyle was apparent. This had resulted from proliferation of the connective tissue at the junction of the synovial membrane, periosteum, and perichondrium. This proliferating tissue had increased in thickness, the deeper layer having been transformed into cartilage which, in turn, was undergoing ossification by means of endochondral ossification. There was slight marginal lipping along one side of the patella, and its articular surface showed slight fraying and pitting. The synovial membrane was slightly thickened in certain areas and the capillaries and small blood vessels were dilated.

FIG. 9

Photograph (natural size) of the right and left knee joints of a rabbit in which patellar displacement had existed in the right knee joint for a period of twenty-eight weeks. The affected joint is greatly widened and deformed. The original articular cartilage of the femur has almost entirely degenerated and marginal overgrowth has occurred along both the medial and the lateral perichondrial borders.

After eight weeks of patellar displacement, the changes noted were very similar to those just described but more extensive. (See Figure 12.) The recently formed patellar groove projecting from the medial condyle was covered by a thick layer of fibrocartilage. In its deepest portion, the cartilage had assumed a columnar arrangement, similar to that seen in an epiphysis, and was undergoing endochondral ossification. One zone of proliferating cartilage, resembling an epiphyseal cartilage plate, was observed between two recently formed areas of bone. In addition, there was noted almost complete disappearance of the articular cartilage over

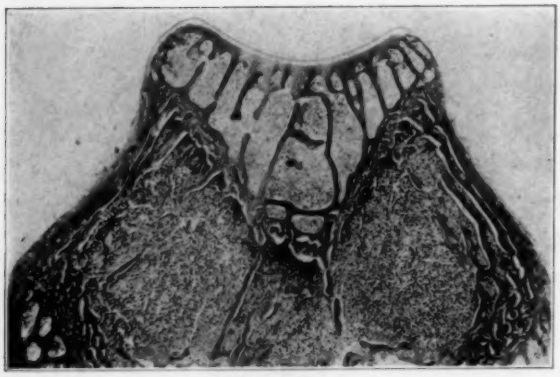

FIG. 10

Photomicrograph (× 5) of section from a normal knee joint of a rabbit, showing the articular surface of the femur. This section and those illustrated in Figs. 11, 12, and 13 are from approximately the same levels. In this rabbit the lower femoral epiphysis is ossified.

the medial epicondylar ridge. The underlying bone was more dense because of increased endosteal activity. The synovial membrane and subsynovial tissues showed dilatation of the small vessels and slight infiltration of the tissues with lymphoid and mononuclear cells.

In the twelve-week specimens, the medial marginal lipping was more advanced, the articular cartilage was thinner, and the calcified zone of cartilage was disrupted in several places. Bone formation was observed in the synovial membrane some distance from the femoral condyle. The synovial membrane was moderately hypertrophied, very hyperaemic, and covered with fibrin in certain regions.

After twenty-eight weeks of patellar displacement, the original articular femoral cartilage had almost completely disappeared. (See Figure 13.) The subchondral bone was exposed through wide gaps in the calcified zone of cartilage. The marginal lipping of the medial femoral condyle consisted of dense, well-formed, and orderly arranged bone trabeculae supporting the newly formed articular surface which consisted for the most part of fibrocartilage. Fibrillation and degeneration of this imperfect articular cartilage had taken place. Sections from this joint and the previous ones indicated that the

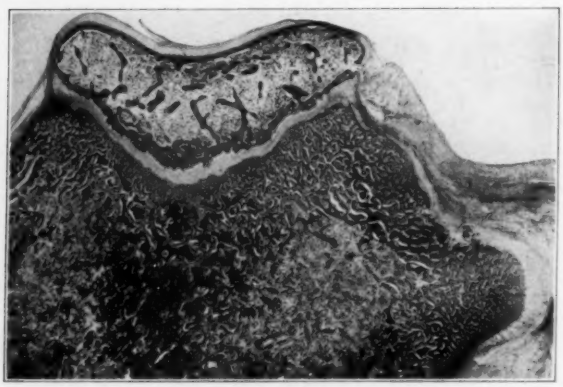

FIG. 11

A cross section through the patellar surface of the femur is shown in this low-power photomicrograph (× 5). Note the atrophy and splitting of the articular cartilage and the marked new bone formation on the medial condyle beneath the newly formed patellar groove. This bony overgrowth has resulted from endochondral ossification of the proliferating connective tissue at the point of reflection of the synovial membrane onto the periosteum and perichondrium. Note that the deeper layer of newly formed connective tissue has acquired the arrangement of an epiphyseal cartilage. The epiphysis is open and growing in this joint.

marginal lipping had resulted because of proliferation of the connective tissue at the perichondrial border of the articular surfaces, with subsequent differentiation into cartilage and replacement by bone. Irregular bony excrescences had occurred elsewhere in this joint because of a similar but uneven proliferative activity.

FIG. 12

Photomicrograph (× 5) like that in Fig. 10, showing more pronounced reconstruction of the femoral end after patellar displacement over an eight-week period.

FIG. 13

Photomicrograph (× 5) similar to Figs. 11 and 12, showing almost complete destruction of the original articular surface of the femur at the left. The proliferative changes previously illustrated have resulted in the formation of a new articular surface covered by imperfect fibrocartilage which is supported by dense but well-ordered bone. Patellar displacement existed for twenty-eight weeks in this joint.

From these observations, it is apparent that the chief characteristics of degenerative joint disease—namely, degeneration of articular cartilage, condensation of subchondral bone, and marginal lipping—do occur soon after displacement of the patella. That similar intra-articular changes develop at an early age in the human knee joint as a result of patellar displacement is well illustrated in the following case.

CASE REPORT

Mrs. H. L. M. (M. G. H. No. 320,382), thirty-seven years of age, entered the Hospital because of recurring pain in the knees. This symptom had first been noted at the age of twelve. The patient stated that the knees became dislocated if she turned her ankle, tripped, walked on rough ground, or turned suddenly. She had always been able to replace the displaced patellae. Following such displacement, the knees had been swollen, tender, stiff, and painful on walking, for a period varying from a few days to a week. Such dislocation had recurred frequently up to the age of twenty-three. She then remained practically symptom-free up to the age of thirty-six, except for occasional swelling of the knees, due to lateral displacement of the patellae. During the year prior to hospital entry, the condition recurred repeatedly in the right knee. She finally entered the Hospital because of increasing pain and disability of two months' duration.

Physical examination was essentially negative, except for the knees and under-

FIG. 14-A

FIG. 14-B

FIG. 15-A

FIG. 15-B

Roentgenograms (anteroposterior and lateral) of the left and right knee joints of a woman, thirty-seven years old, who, since the age of twelve, had been subject to repeated displacement of the patellae. This anatomical derangement had occurred more frequently in the right joint where the degenerative joint changes were more advanced.

nutrition and dental caries. Examination of the lower extremities revealed moderate bilateral genu-valgum deformity and pronated feet. The knees were moderately enlarged, the right more than the left, because of synovial-membrane thickening and increase in size of the infrapatellar fat pads. No fluid was demonstrable. The patellae were displaced laterally and tilted posteriorly. The internal femoral condyles were unduly prominent. Joint motions were accompanied by marked crepitus, but were not painful except when the knees were flexed beyond 90 degrees on the right and 110 degrees on the left.

Routine blood and urine examinations were negative. Both the Wassermann and the Hinton tests were negative.

Roentgenograms revealed marginal proliferation of the condyles, more marked on

the right. Marginal proliferation of the patellae was also present, again more marked on the right. Two large masses and one smaller one, having the appearance of bone, were demonstrable in the right quadriceps pouch. (See Figures 14-A, 14-B, 15-A, and 15-B.)

The right knee was opened through a median parapatellar incision. The synovial membrane lateral to the patella appeared thickened. The masses described were easily found. The smaller one was lying free; the two larger masses were attached to the overhanging lateral margins of the patella. The articulating surfaces showed marked degenerative changes and considerable marginal lipping. There was an area of eburnated bone on the lateral condyle beneath the patella. The synovial membrane was resected, and the masses and thick bony excrescences from the upper lateral margin of the patellar surface of the femur were removed.

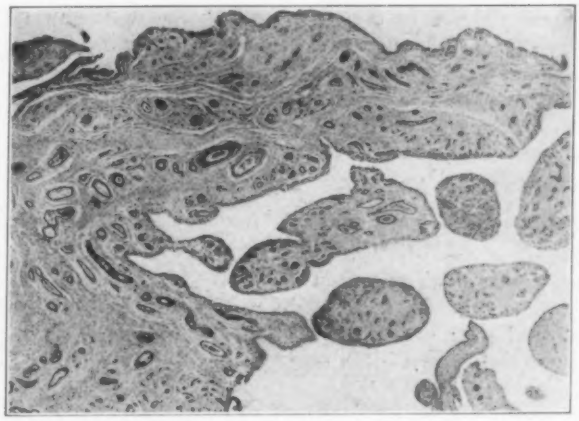

FIG. 16

Photomicrograph (× 20) of the synovial membrane from the right joint illustrated in Figs. 13 and 14-B. Although moderate villous hypertrophy has occurred, there is no sign of active inflammation.

Microscopic examination: The synovial membrane from the quadriceps pouch showed no great variation from the normal. The villi, which were slightly larger and somewhat more numerous than those seen in a normal joint of a person of the same age, were covered by normal-appearing layers of synovial-lining cells. Scattered mononuclear leukocytes and lymphoid cells were present, but polymorphonuclear leukocytes were rarely observed. Definite pathological changes were present in the thickened synovial-lining tissue obtained from an area lateral to the patella. Numerous, fairly large, and often branching villous projections were noted. (See Figure 16.) These consisted of vascular and somewhat oedematous connective-tissue cores bounded by a few poorly defined layers of synovial-lining cells. There was no significant inflammatory cell infiltration in any of the sections examined. Sections from the overhanging margins of the articular surfaces of the patella and the femur were examined. (See Figure 17.) These osteophytes or spurs consisted of cancellous bone surrounded on the upper and outer surfaces by uneven hyaline cartilage, showing considerable fibrillation of the matrix and

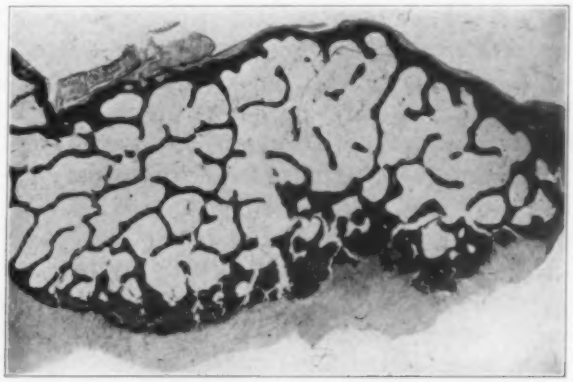

FIG. 17

The extent of the marginal lipping is demonstrated in this photomicrograph (× 5) of a bony excrescence projecting from the articular margin of the patellar surface of the femur.

uneven distribution of cartilage cells. The surface zone of such cartilage was pitted, frayed, and, in places, covered by layers of spindle cells which had the appearances of proliferating fibroblasts. Portions of these osteophytes were bounded by compact bone. Such areas were, in turn, covered by vascular connective tissue, the surface layers of which were not materially different from synovial-lining tissue. Again, no signs of inflammation were observed.

Sections through the bony masses removed from the joint showed them to consist of bone and cartilage, each of which was surrounded by a zone of proliferating fibrous tissue. Histological study of numerous sections indicated that the sequence of events in the growth of these bodies was as follows: proliferation of connective-tissue cells at the periphery, differentiation of such cells and the intercellular substance into hyaline cartilage, and, finally, the calcification of much of the cartilage thus formed. Several areas in the interior of the loose bodies showed cystic degeneration. There was no positive evidence to indicate the origin of these loose bodies by detachment of the marginal osteophytes described.

DISCUSSION

Since there is difference of opinion as to the exact manner in which the intra-articular changes of degenerative joint disease are produced, it seems desirable to discuss in detail the development of such intra-articular changes resulting because of a lone joint abnormality,—namely, patellar displacement.

That degenerative and proliferative changes in the cartilage, similar to those of degenerative joint disease, can be produced experimentally has been demonstrated by Kroh and Wehner. Kroh attributed the changes following resection of one femoral condyle to the incongruity of the joint surfaces. Wehner concluded that the abnormal use of the joint, following patellar resection, was an important factor in the production of the resulting intra-articular changes. Our experimental findings lend support to such conclusions, but are in disagreement with those of Key who concluded that simple resection of a small piece of cartilage from the patellar groove was of itself an adequate cause for such intra-articular changes. Resection of articular cartilage or of cartilage and subchondral bone is not the cause of intra-articular pathology unless coincidental displacement of the patella or some additional injurious factor results because of the operative procedure [5, 6, 7]. Ely and Cowan were unable to produce hypertrophic arthritis by cauterization of the articular cartilage, as previously described by Axhausen, and were forced to conclude that such changes were the result of faulty technique and extensive damage by the electrocautery.

The degenerative and hypertrophic changes in cartilage observed in the present experiments, following simple patellar displacement, were most marked in the joints in which the abnormality was greatest or had existed for the longest time. As in human degenerative joint disease, the first change noted was that of degeneration of the hyaline cartilage [12], appearing on the epicondylar ridge which had articulated with the displaced patella. (See Figures 5 and 6.) In these same joints, the cartilage of the non-articulating femoral patellar surface showed progressive signs of atrophy similar to the atrophy of disuse previously described [6, 8, 9].

(See Figures 7, 9, and 13.) These findings and observations on so-called normal human knee joints of various ages [3] suggest that the nourishment and maintenance of normal cartilage is dependent in part on adequate lubrication by synovial fluid, which, in turn, is best maintained by normal articular apposition and use. They further suggest that undue pressure and friction [4] or absence of normal articular apposition will lead to accelerated articular-cartilage degeneration. These changes occur more rapidly in those areas where the ability of articular cartilage to repair itself is most limited [5, 6, 7].

In certain of these joints, the continued pressure and friction of the displaced patella resulted not only in the complete loss of the articulating cartilage but also in condensation or eburnation of the underlying exposed subchondral bone. (See Figures 5 and 6.) Such condensation of bone was evidently due to stimulation of the endosteum. It was never observed until the articular cartilage was completely eroded. Although the non-articulating surfaces of such joints revealed areas in which equal or greater degrees of articular-cartilage degeneration had taken place, there was never any evidence of eburnation of the underlying bone. (See Figures 9 and 13.) This and similar findings demonstrable in human knee joints would seem adequate evidence that undue pressure and friction produce sufficient stimulation of the endosteum to bring about condensation of the subchondral bone.

The changes in the synovial membrane in certain of these experiments were more marked than is ordinarily observed in degenerative joint disease. Such synovial-membrane hypertrophy and villus formation were also observed in the case herein reported. Loose bodies of cartilage, or of cartilage and bone, may be encountered in degenerative joint disease. Their exact mode of formation is not always certain. They may represent detached fragments of the marginal lipping or metaplastic transformation of hypertrophied synovial villi. They were encountered only in one experiment in this study.

One of the most characteristic roentgenographic features of degenerative joint disease, as observed in the human, is the marginal overgrowth or lipping (osteophytes and spurs). Although this marginal overgrowth is looked upon as secondary to the primary degenerative changes [3, 12] its production has never been adequately explained. Parker, Keefer, Myers, and Irwin concluded that such bony projections occurred in deranged joints, usually after flattening of the joint surfaces had taken place. They state that, because of such flattening of the joint surfaces, the marginal bone and cartilage are forced outward and downward, or, if depressions exist in the marginal articular cartilage, the projections may be forced upward. Such an explanation would seem adequate in the case of the extensively altered joints of older people, but it does not explain the varying forms and degrees of lipping observed in younger individuals [3]. In this age group, one notes increasing prominence at the point demarcating the junction of the synovial membrane and the periphery of the articular

surface before any significant flattening of the joint surfaces is demonstrable. With increasing age, this zone becomes increasingly more prominent and in many instances progresses to fully developed lipping.

In these experiments and in those previously done on dogs (Figs. 3, 4, and 5), it was noted that the earliest detectable marginal proliferation occurred at the point where the synovial membrane reflects onto the perichondrium of the articular margins. This marginal zone is very vascular and possesses greater reparative and proliferative ability than do the avascular central areas. That the tissues in this region are subjected to frequent stress and strain can be readily demonstrated by examining a partially opened joint. On doing so, one notes that extension and flexion of the joint result in alternating tension and relaxation of the synovial membrane at its insertion. This oft-repeated tension would seem to serve as sufficient stimulus to this vascular fibrous tissue to cause it to proliferate. Such proliferating fibrous tissue (perichondrial and periosteal) being in intimate contact with bone and cartilage may become differentiated into fibrocartilage or hyaline cartilage and bone. Once these proliferative changes have taken place, sufficient alteration in the normal mechanics of the joint may ensue to allow the changes to progress more rapidly. Anatomical alterations—such as genu valgum, genu varum, and patellar displacement—undoubtedly greatly increase the stress and strain in this region and, in consequence, there results a more rapid and more extensive marginal proliferation. In one experiment a new articular surface had developed in as short a time as four weeks; whereas, in another, in which the displacement was of twelve weeks' duration, the new articular surface was supported by well-arranged bone trabeculae. (See Figures 11, 12, and 13.) The direct pressure of the displaced patella on the underlying tissues undoubtedly is in part responsible for the newly formed patellar groove.

From these studies it is apparent why extensive degenerative joint disease may develop in relatively young individuals with any type of patellar displacement. This being the case, corrective treatment should be instituted sufficiently early to prevent the development of irreparable joint damage.

These studies further indicate that the increased wear and tear to which a joint is subjected as a result of a lone joint abnormality (patellar displacement) is of itself an adequate cause for extensive degenerative joint disease. In these experiments, one can feel quite certain that the intra-articular changes represented a local disease process and not a manifestation of some systemic infectious, metabolic, or endocrine disease, because the control joints showed no intra-articular abnormalities. The changes encountered can be accounted for on the basis of several factors: (1) undue pressure and friction, causing loss of cartilage and eburnation of bone; (2) absence of normal intra-articular apposition and, in consequence, of normal lubrication by the synovial fluid, with resulting cartilage degeneration and atrophy; and (3) undue tension of the synovial membrane

at the site of its attachment, with resulting proliferation of the underlying fibrous connective tissue which, undergoing changes, results in marginal proliferation. This additional evidence lends support to the theory that degenerative joint disease may, in most instances, represent nothing more than the changes due to wear and tear, resulting from increasing age and long-continued daily use. Such changes, due to wear and tear secondary to long-continued use, are much more marked in the case of articular cartilage than of other body tissues because this cartilage has a limited source of nourishment and a very limited ability to repair itself.

SUMMARY

1. The patellae of rabbits can be displaced without opening or otherwise injuring the knee joint. Such patellar displacement is of itself adequate cause for degenerative and hypertrophic changes in cartilage, similar to those of degenerative joint disease.

2. The undue pressure and friction of the displaced patellae resulted in rapid loss of the underlying articular cartilage with subsequent eburnation of the subchondral bone.

3. The absence of normal patellar apposition and, in consequence, of lubrication of the non-articulating surfaces with synovial fluid was responsible for articular-cartilage degeneration and atrophy.

4. Proliferation of the connective tissue at the perichondrial margins of the articular surfaces led to well-defined marginal overgrowth. This marginal overgrowth was sufficiently marked to form a new patellar articulating surface on the medial side of the femur.

5. The repeated stretching of the synovial membrane at its insertion, coincident with full extension, would seem adequate stimulus to cause the very vascular, undifferentiated, perichondrial connective tissue to proliferate sufficiently to result ultimately in marginal lipping. Such marginal proliferation occurs to some degree in all joints with increasing age and long-continued use, but develops much more rapidly in joints with anatomical derangements such as patellar displacement.

6. The clinical and pathological findings from one patient with bilateral displacement of the patella were identical with those of degenerative joint disease.

7. These studies emphasize the importance of early corrective measures in patients with displaced patella if irreparable joint damage is to be prevented.

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OS ACROMIALE—A CONTESTED ANOMALY*

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Some time ago the writer was called in by the Compensation Commissioner to express an opinion in the case of a longshoreman, thirty-eight years of age, who had sustained an injury to one shoulder. It was the author's duty to ascertain whether a certain fracture of the acromion, as seen in a roentgenogram, was recent or old. After studying the film, it was decided that both shoulders should be x-rayed in the supero-inferior position before a decision was made.

The writer was then able to point out to the Commissioner that:

1. There was no difference whatever in the outline of the bony gap (the alleged fracture line) between the terminal end of the acromion (pre-acromion and meso-acromion) and the basal part of the acromion (meta-acromion and basi-acromion) in the injured and in the non-injured shoulder.

2. The bony gap was in the same direction and plane in both shoulders.

The diagnosis was bilateral os acromiale, not due to an injury.

The Commissioner accepted this diagnosis, but the plaintiff's physician could not be convinced that this gap in the acromial process was due to non-ossification of the intervening cartilage. At that time the author could not refer him to roentgenographic evidence on this subject in the English literature. Since then, other contested cases of similar nature have arisen and it has been possible to show, through an English translation of Köhler's book, a reference to the roentgenographic appearance of the os acromiale. It is because of the paucity of material on this subject in the English literature that the author is reporting twenty-five cases of os acromiale found in a study of the routine roentgenographic examinations of 1800 shoulder girdles.

In reviewing some of the literature on this subject, one is impressed by the tenacious views held by Struthers and his school,—namely, that a division line in the acromion is a form of ununited fracture; even the bilateral appearance, he explained, is due to fractures, not necessarily simultaneous.

In opposition to this view, Bernardeau in his thesis on this bone shows, by a comparative anatomical study, that such a separate bone formation might exist as an atavistic trait, having found it present in the sorex and in the chrysochloris.

Anatomists are at present more disposed to the view expressed by Bernardeau. Gray states: "Failure of bony union between the acromion

* Approved for publication by the Surgeon General, United States Public Health Service.

and the spine sometimes occurs, the junction being effected by fibrous tissue or by an imperfect articulation; in some cases of supposed fracture of the acromion with ligamentous union, it is probable that a detached segment was never united to the rest of the bone." Cunningham states that "failure of union" [of the different ossifying centers of the os acromiale] "may, however, persist throughout life". In a later edition, this author goes further and adds: "The greater part of the acromion is *throughout life a separate bone*, united to the rest of the bone by periosteum and a strip of cartilage or by a synovial joint which appears like a line of fracture in the x-ray photograph; the condition is usually alike on the two sides."

The frequency of this anomaly, as reported by anatomists, varies to such an extent as to warrant belief that their divergence of opinion is based on their different concepts of the nature and appearance of an os acromiale. Hence, McAllister reported an incidence as high as 15 per cent.; Pfitzner, in a group of personally examined cases, gave the frequency as 7 per cent.; and Gruber found only three cases in 100 cadavera. In Gruber's report, however, it must be noted that he excluded all forms which did not have a distinct joint with synovial membrane.

Roentgenographically, there is even greater dissent. Lilienfeld, reporting on 200 shoulder-girdle examinations in the anteroposterior (sagittal) plane, found none. Köhler did not come across any in his thirty-one years of experience; whereas Becker, in 160 cases, examined 240 shoulders both in the anteroposterior (sagittal) and in the axial planes and found four cases of unilateral and one case of bilateral *atypical* os acromiale.

Our 1800 shoulder-girdle examinations, made in the anteroposterior and the oblique positions, disclosed *twenty-one typical* and *four atypical* cases of os acromiale. Since we used the axial examination only in contested cases, it is quite possible that we missed a few cases of the atypical type.* From the practical viewpoint they were not disturbing, hence, not significant. With the addition of the axial examination as a routine, these smaller or atypical types might also become contested cases; but then the differential diagnosis is more obvious.

To appreciate further the varieties of this anomaly, we should acquaint ourselves with the development of the acromion. According to Folliasson and Neumann, at about the fifteenth to the eighteenth year, there appear three separate ossifying centers at the epiphysis of the acromion: a pre-acromion, a meso-acromion, and a meta-acromion (Fig. 1). The fourth, or basi-acromion, is a continuation of the center for the scapula which appears at about the third month of foetal life. At about twenty-two to twenty-five years of age, these centers fuse with the base

* Since the original study of these 1800 shoulders, 1000 more cases have been followed. Each time that a diagnosis of os acromiale was made, the patient was called for reexamination and the other shoulder girdle was examined in the usual anteroposterior and also in the inferosuperior positions. There were twenty-seven cases of os acromiale observed. Only twenty-one patients came back and of these thirteen had bilateral and eight unilateral os acromiale. The frequency is 2.7 per cent., nearly 62 per cent. being bilateral.

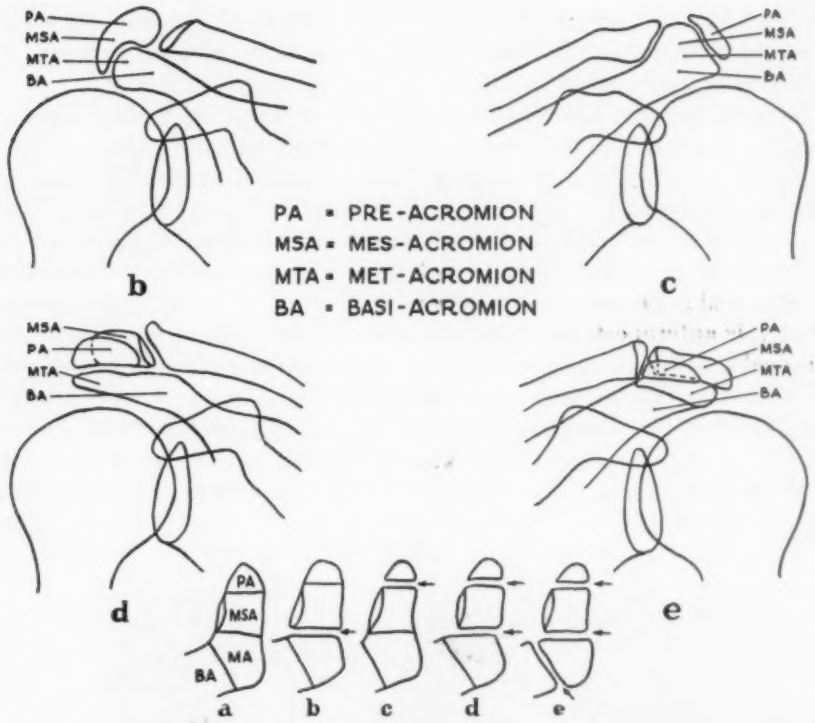

FIG. 1

Diagram representing the different ossific centers which constitute the adult acromion. *PA* = pre-acromion; *MSA* = meso-acromion; *MTA* = meta-acromion; and *BA* = basi-acromion. The earliest center is that of the basi-acromion which is a continuation of the center for the body of the scapula, appearing at about the third month of foetal life. One, two, or three bony centers appear almost simultaneously at about the fifteenth to the eighteenth year and fuse together to the basi-acromion at about twenty-two to twenty-five years of age. Failure of union may occur between the pre-acromion and the meso-acromion, between the meso-acromion and the meta-acromion, between the meta-acromion and the basi-acromion, or a combination of any two or even all centers. The most common non-union is between the meso-acromion and the meta-acromion. In regard to the other centers, the pre-acromion is fused to the meso-acromion and the meta-acromion is fused to the basi-acromion as in *b*. This constitutes a typical os acromiale. Any other location of failure of union, as in *c*, *d*, and *e*, is atypical. (Redrawn from Folliasson.)

of the acromion. When there is failure of union of any one of these centers to its neighbor, the resulting separate bone is an os acromiale; hence, the four possible forms of os acromiale. The most frequent form is union of pre-acromion and meso-acromion, union of meta-acromion and basi-acromion, but separation between meso-acromion and meta-acromion. (See Figure 1, *b*.)

Bernardeau and Symington described the existence of a distinct joint cavity in this most frequent form, with capsular ligament and synovial membrane lining the joint cavity. In twenty-four cases, Bernardeau found twenty with diarthrodial and four with amphiarthrodial types of joints. Symington observed that the younger a person is,

the greater is the possibility for the interacromial joint to have its medial end included in the acromioclavicular space. The older the person is, the less is this possibility.

Anatomically, the os acromiale has been classified under four principal types. The most frequent is the *quadrangular;* next, the *oval;* third, the *triangular;* and, rarely, the *falciform.* Since the anatomical classification of the acromion is based on its appearance as viewed from *above,* whereas the common roentgenographic examination is based on the *anteroposterior* (sagittal) view of the shoulder, the precise details of the anatomical appearance will not be studied here. It must be remembered that this anteroposterior roentgenogram of the shoulder is neither a true coronal cross-sectional nor a sagittal cross-sectional view of the acromion as seen in the anatomical superior view; therefore, these types can only be approximated roentgenographically. In doubtful cases, the anatomical view may be reproduced by taking an inferosuperior view (Berent and von Hecker), which is an axial view of the shoulder girdle seen roentgenographically.

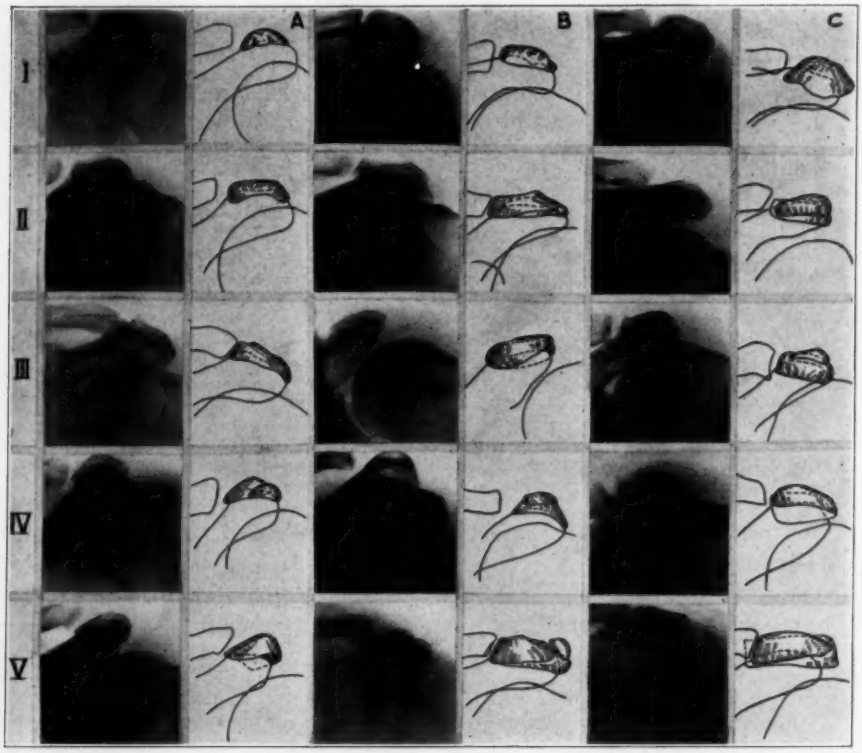

FIG. 2

In this figure are represented fifteen different sizes or forms of os acromiale as seen in the anteroposterior views. On the right of each view is its sketch to facilitate better visualization of the separate superimposed "bonelet", os acromiale, on the acromion.

Since the material for this study consisted of the usual antero-posterior and oblique views of the shoulder girdle, our description of the os acromiale is primarily based on its roentgenographic appearance as seen in the first of these two views. It is well to remember that the direction of the central ray determines the roentgenographic appearance of the upper peripheral border of the acromion, and hence the type will vary with deviation of the direction of the central ray. This principle can be demonstrated by the fact that the quadrangular type may appear slightly *ovoid* or more *flattened*, depending on whether the central ray has been directed lower or higher than the glenoid cavity.

ROENTGENOGRAPHIC FINDINGS

The roentgenographic appearance of the os acromiale is not uniform because irregularity in shape, size, position, and mode of articulation with the clavicle is due to the random chance formation of this bone. Nevertheless, in this study, it has been found that certain recognizable factors recur with sufficient frequency to justify a topographic description and nomenclature for the os-acromiale shadow as seen roentgenographically.

In Figure 2, the roentgenograms of fifteen different types of os acromiale are given, each being supplemented by a drawing, intended to facilitate the visualization of the os acromiale as an entity. The left shoulders are shown in reverse position to facilitate arrangement. The ages of the patients ranged from twenty-eight to seventy-five years, the average age being forty-seven years. In all of these cases, the os acromiale is seen as a separate shadow, roughly triangular in shape, varying in size*, and appearing to sit unevenly astride the angle of the acromion. The transverse axis is about three times as long as the vertical diameter, and is usually tilted inward for about 15 degrees from the horizontal toward the upper lip of the crest of the spine. The density of the upper half of the shadow is the same as that of the lateral end of the clavicle; the lower half shows two dense lines with or without a darker linear shadow between these two lines. The upper line is horizontal and represents the basal part of the acromion which is continuous with the spine at the angle where the crest and the lateral border of the spine meet; the lower line is oblique, upward, and outward, and represents the basal part of the os acromiale which has failed to fuse to the rest of the acromion. This line is lower because of the overlapping of the shadow of the os acromiale on the acromial shadow. There may be more than two lines, as in atypical cases, but there must be *at least two;* otherwise, each downward projected

* The shape and the size of the os acromiale vary depending upon whether non-fusion took place between pre-acromion and meso-acromion, meso-acromion and meta-acromion, or meta-acromion and basi-acromion. In the most common form of separation found (between meso-acromion and meta-acromion (Fig. 1, *b*) the size of the os acromiale varies from one centimeter in length, one-half a centimeter in width, and three-quarters of a centimeter in height to two and one-half centimeters in length, three centimeters in width, and three-fourths of a centimeter in height. The following descriptive names have been given to the different shapes observed in Figure 2: Hemispheric, *A-I;* Plane, *A-II, A-III;* Toque, *A-IV, B-II;* Helmet, *A-V, B-IV, B-V;* Cube, *B-III, C-I, C-II, C-III, C-IV, C-V.*

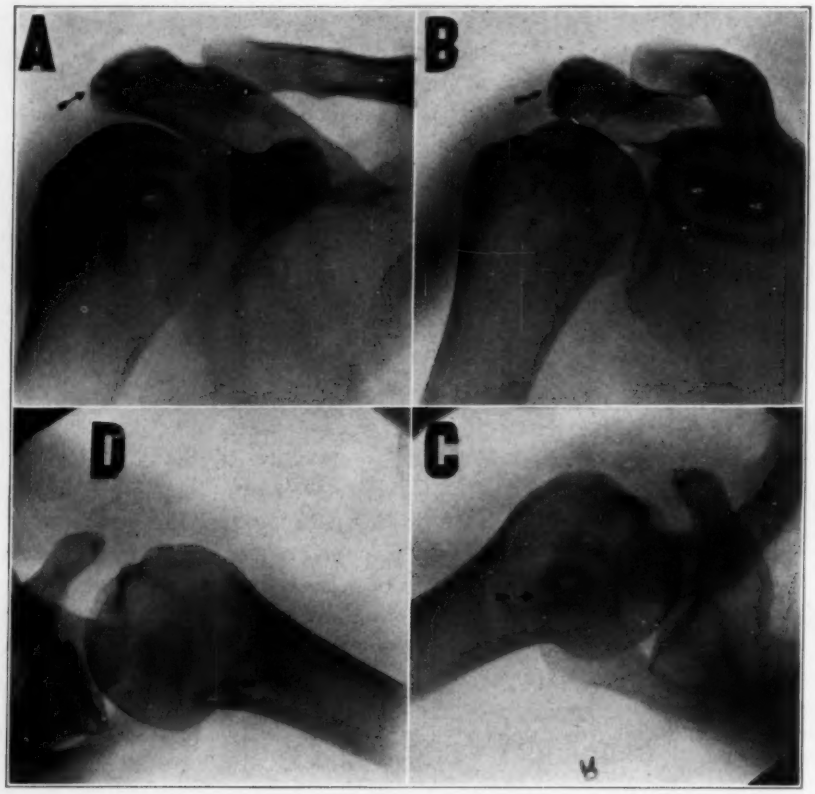

FIG. 3

Appearance of a typical os acromiale in the three different views: (*A*) the ordinary anteroposterior, (*B*) the oblique, and (*C*) and (*D*) the inferosuperior of both sides. This patient was a man, thirty-two years of age, who had sustained an injury to the right shoulder as the result of a fall. In *A* there is a suspicious linear shadow, shown by the arrow. In *B*, the linear shadow is more prominent, and a separate bone, cone-shaped, can be discerned. However, in *C*, it is evident that the separate piece of bone is separated from the rest of the bone by a uniform band of non-osseous tissue; the borders are not sharp, nor are they ragged. The same findings are also present in the other shoulder (*D*).

acromial end would be taken for an os acromiale. The median border is sharply linear and denser, usually parallel to the adjacent long diameter of the clavicle, forming with it a *joint space between the os acromiale and the clavicle.* The superior border is convex, continuous with the medial border internally.

DIFFERENTIAL DIAGNOSIS

The problem of deciding between a fracture and an os acromiale can be resolved by the following salient factors:

1. *Bilaterality* occurs in about 62 per cent. of the cases of os acromiale.

2. The *borders* of the problematic shadow are *rounded* and the

cleavage line is *uniform* in the case of an os acromiale, whereas the *borders* are *sharp* and the *cleavage line* is *ragged* in the case of a fracture.

3. The *position* of the shadow is at the same or at a higher level than the remaining part of the acromion in the case of an os acromiale, whereas the *position* of the shadow is at a lower level in the case of a fracture.

To these three factors may be added the fact that pointed borders indicate associated osteo-arthritis. Also, fractures of the acromion are less frequent, only ten cases having been found in the examination of 1800 shoulder girdles; the majority of these were associated with other minor fractures or dislocations of the shoulder girdle.

SUMMARY

Roentgenographic examinations of 1800 shoulder girdles, made in the sagittal plane, disclosed twenty-one typical and four atypical cases of os acromiale. At least six of these cases have been contested as being possible fractures. An additional study of 1000 cases gave a frequency of 2.7 per cent., 62 per cent. being bilateral. A supero-inferior examination facilitates the making of a differential diagnosis.

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LESIONS OF THE LUMBOSACRAL SPINE

Part II. Chronic Traumatic (Postural) Destruction of the Lumbosacral Intervertebral Disc

BY PAUL C. WILLIAMS, M.D., DALLAS, TEXAS

The roentgenographic appearance of this lesion is shown in Figure 1.

Under this grouping fall all mechanical alterations of the low spine, which cause an uneven distribution of weight on the intervertebral discs. This results in an early pathological degeneration of that portion of the disc which is under abnormal stress. Due to the structure of the lumbosacral region and to the erect posture of man, this stress is exerted only on the posterior and lateral margins of the lower spinal discs.

Fig. 1

Chronic traumatic or postural destruction of the lower lumbar and lumbosacral intervertebral discs (retouched). Note the subluxated facets and constricted foramina.

Etiology

A lateral tilt of the first sacral vertebra, due to a short leg, or to hemiatrophy, or to a congenital malposition of this segment, is the most common cause of increased pressure on the lateral aspect of the lumbosacral disc. Such a condition causes a lateral tilt of the sacral table. If the spine were a rigid structure, which moved with the first sacral segment, a deviation of the entire trunk toward the low side would result. This would severely disturb

the center of gravity of the body in its relationship to its base of support. Since the spine is a flexible column, the center of gravity is maintained over its base of support by flexing the spine laterally toward the long extremity. This results in an abnormal stress on the lateral aspects of the lumbosacral and lower lumbar intervertebral discs.

A lumbosacral lordosis is the common cause of pressure on the posterior margin of the lower lumbar and lumbosacral intervertebral discs.

Posture is undoubtedly responsible for the vast majority of painful backs. The assumption that at least 60 per cent. of all persons past the age of forty years are potentially subject to pain in the lower part of the back the author believes is justified. That many persons escape is due to the lack of physical exertion and strain at this site.

Provided that the pull was slight and exerted over a period of many months, it would undoubtedly be possible to extend a metacarpal phalangeal articulation until the finger contacted the dorsum of the hand. The pain experienced from such a procedure would no doubt be of low grade and aching in character. However, if at any time during the course of such a procedure a sudden increased force was applied, severe pain would follow, which would require several days to subside. If there was a nerve so situated that it would be compressed as extension was continued, the person would experience pain throughout the distribution of that nerve.

A similar situation is constantly taking place in the lumbosacral region of the spine. The sacrospinalis group of muscles are continually in action when a person is moving about in the erect position, thus exerting a constant extensive force on the low spine. As a result of the sedentary life of most adults, the weakened abdominal muscles continue to get weaker from disuse, while their antagonistic sacrospinalis muscles continue to get stronger from overuse. This permits a protrusion of the abdomen which tends to shift the weight forward and thus to disturb the center of gravity. This disturbance in the center of gravity is compensated for by increasing the extension of the lumbosacral spine, thereby shifting the weight of the thorax posteriorly. During this process there is a constantly increasing force being exerted on the posterior margins of the intervertebral discs of the lower lumbar and the lumbosacral regions. The discs become wedge-shaped in appearance and a subluxation of the joints formed by the articular facets is evident by roentgenographic examination, as shown in Figure 1.

If, at any time during this process of extension of the lumbosacral spine, a sudden increased extensive force is applied, severe symptoms in the form of pain in the lower part of the back will follow. The mechanics involved in such an injury is a sudden increase in the degree of subluxation of the articular facets. They have violated what Brown has described most clearly and has spoken of as the "Factor of Safety Motion".

After the extensive force has been continued long enough to permit the posterior margins of the vertebral bodies to approximate one another closely, the foramina are so constricted that an irritation of the funicular

portion of the nerve results and pain is experienced throughout the distribution of that particular nerve.

The two principal types of postural backs which cause an increase in the lumbosacral lordosis are those commonly spoken of as the round hollow and the round.

It is the writer's opinion that the kinesiological action involved in bringing about such postural deformities is the same in both types; the difference in the deformities is dependent upon constitutional types.

The round back is most commonly seen in patients who present a relaxed attitude. They are usually inclined to be thin. Their joints are loosely constructed and hyperextension of elbows, knees, and hips is a common finding. They present a poor muscle tonus and give the impression of a disturbance or imbalance of the internal glands of secretion. The feet and hands are usually long and narrow, as is also the thoracic cage. The thoracic and abdominal viscera present findings characteristic of their constitutional types. These have been described by Goldthwait.

The round hollow back is most commonly seen in patients who are inclined to be obese. Their joints are firmly constructed and frequently are found to fall a few degrees short of complete extension. They present a good muscle tonus and are inclined to be more energetic than those who present the round back. The hands and feet are either short or medium in length and are firmly constructed. The thoracic cage is short and broad. The visceral organs vary considerably, both in position and in shape, from those of patients with the round type of back.

Kinesiology

In dealing with postural disturbances of the spine, a thorough understanding of the muscles whose actions play a part in the motion of the lumbosacral spine is essential. Figure 2 demonstrates schematically these muscles. A contraction of the sacrospinalis group, when a person is in the erect or in the extended position, results in an extension of the lumbosacral spine, causing a compressive force to be exerted on the posterior margins of the intervertebral discs at this site. The anterior abdominal muscles are antagonistic in their action, in that they lift the front of the pelvis and thereby reduce the extension of the lumbosacral spine, thus shifting the stress from the posterior to the anterior margins of the intervertebral discs. The gluteus maximus, taking its origin from the posterior portion of the ilium and inserting into the lateral aspect of the upper end of the femur, when in contraction, tends to draw the pelvis down from behind and to force it up in front, the axis of rotation being the hip joint. The action of the glutei, therefore, aids that of the anterior abdominal muscles in reducing the extension of the lumbosacral spine. The hamstring muscles take their origins from the ischial tuberosities which are behind the axis of rotation of the pelvis. A contraction of this group aids the gluteus maximus in drawing the posterior half of the pelvis down and in lifting up its anterior portion. With the exception of

the iliopsoas, the hip flexors take their origin from the anterior half of the ilium. A contraction of these muscles tends to draw the anterior half of the pelvis down and to force the posterior half of the pelvis up, thereby aiding the sacrospinalis group in extending the lumbosacral spine. The psoas muscles take their origin from the transverse processes and the posterior halves of the lumbar vertebrae,—behind the vertical axis of the vertebral bodies. When a person is in an erect or extended position, a contraction of these muscles causes an extension of the lumbosacral spine, thereby aiding the sacrospinalis and the hip-flexor groups. This is not true when the hips have been flexed to an angle of 45 degrees or more. In such a position, their point of insertion has been shifted forward and their action is either that of vertical compression or of anterior flexion of the lumbosacral spine.

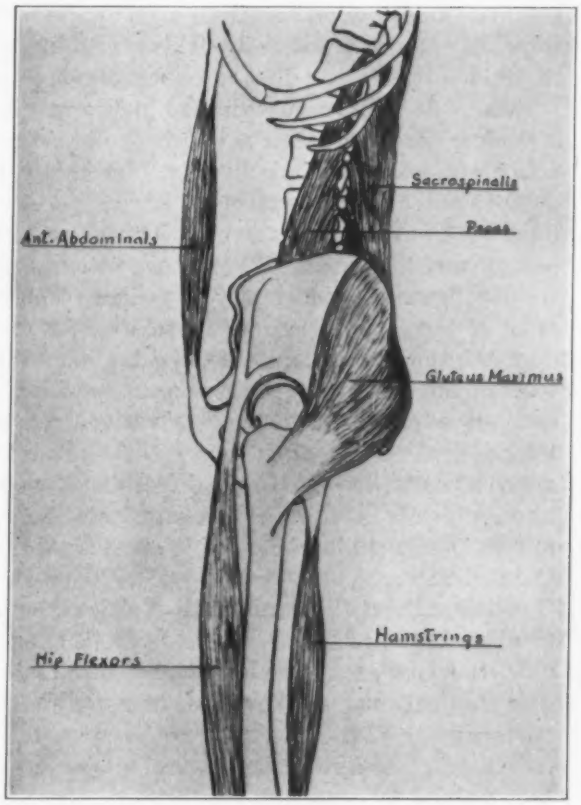

FIG. 2

Schematic drawing, showing principal muscle groups which affect the posture of the lower spine.

It becomes evident from a study of muscle action that extension of the spine is brought about and maintained by the sacrospinalis, by the hip flexors, and, when the body is in the erect position, by the psoas. Since faulty posture is a deformity of the erect position, the psoas muscles must be considered an offending group. It is also evident that the principal muscles whose actions are antagonistic to these are the anterior abdominal, the gluteus maximus, and the hamstring groups.

When an infant progresses from the position of all fours to that of biped ambulation the tendency is for the child to fall forward. In assuming such a posture, there is undoubtedly a passive stretching force exerted in the anterior abdominal and hip-flexor groups of muscles. As the sacrospinalis muscles become stronger, the child gradually gains his

balance and the anterior abdominals are stretched out to accommodate the newly assumed position. This stretching compensation is undoubtedly aided by the fact that these muscles are used but little in the erect position. It is different with the hip flexors. They, too, are subject to a stretching force, but their action in the biped gait is as important as the action of the sacrospinalis muscles. Therefore, due to constant use, they do not undergo a disuse atrophy, and they do not respond to the stretching force applied as do the anterior abdominals. When once the erect posture and the biped gait have been accomplished, the sacrospinalis and the hip flexors are constantly in action. This results in an overdevelopment of these two groups of muscles at the expense of the anterior abdominal, the gluteus maximus, and the hamstring groups. When symptoms appear as a result of the hyperextended position of the lumbosacral spine, it is evident that any conservative or surgical measure which interferes with the action of either one of these two muscle groups will at least afford a partial relief. This is due to the fact that the constant extensive force, which is narrowing the posterior width of the intervertebral discs and gradually subluxating the joints formed by the articular facets, has been released.

The author believes that this explains the relief from symptoms which Ober has obtained in severing the iliotibial band. It is very probable that a Soutter fasciotomy would accomplish the same result. It is also probable that it explains the relief from symptoms obtained by Heyman by stripping the posterior superior iliac spine inferiorly and medially. In individuals who have had a normal adolescent growth similar results can be obtained by passively stretching these two groups and actively developing their antagonistic muscles.

History

The history obtained from patients suffering with symptoms due to chronic traumatic destruction of the lumbosacral and lower lumbar intervertebral discs differs from that in which symptoms are caused by the acute traumatic lesion principally in the age period of onset and severity of symptoms. The thinning of the discs due to postural degeneration usually causes symptoms at some time between the ages of thirty and forty. Occasionally, in those patients who present a relaxed attitude and poor muscle tonus, a history of fatigue and pain, aching in character, coming on near the close of day or after a long automobile journey, is obtained as early as the latter half of the second decade of life. However, the symptoms characteristic of degenerative disc changes do not make their appearance until a later period in life.

The usual history obtained is that near the age of thirty-five, without apparent cause, a chronic pain developed in the lower part of the back. On several occasions, usually following some physical exertion in the form of lifting or stooping, severe attacks of pain occurred which required from several days to weeks to obtain relief from symptoms. Eventually the

pain became chronic and moderately severe in character and radiated into one or both hips down the posterior aspect of the thigh and into the lateral aspect of the calf and the ankle.

It is not uncommon to obtain a history from women suffering from this lesion that symptoms were aggravated severely during pregnancy, and in many cases they are inclined to date the onset of symptoms from pregnancy. This can be explained on the basis that the lordosis is increased severely during such times, particularly in women who naturally present an exaggerated lumbar curve. The writer does not believe that an enlarged uterus can exert pressure on the sciatic nerves.

In late neglected cases it is not uncommon to obtain a history of pain in the anterior thigh (femoral-nerve distribution) in addition to the history which has been mentioned.

Regardless of whether the abnormal stress on the disc which has brought about its early degeneration is due to a pelvic tilt or to an exaggerated lordosis, the history usually reveals that symptoms began in the latter part of the third or of the fourth decade of life.

These patients, like those suffering with the acute lesion, frequently give a history of sleeping on the side, with one or both knees drawn up, or on the face with a pillow under the abdomen. They are unable to work in a stooped position and often complain of pain when bending over a wash bowl or working over a kitchen table, as well as in lifting objects. Long automobile rides usually cause severe discomfort. These patients frequently complain of an aggravation of symptoms following prolonged standing.

Symptomatology

Examination of patients suffering with this lesion reveals that about 15 per cent. present a pelvic obliquity which is frequently due to a short leg. When the patient is viewed from behind, this can be readily observed in that the spine presents a postural scoliosis, the pelvis is tilted, one lateral gluteal fold is lower than the other, and the vertical fold forms an angle with the perpendicular. These patients may or may not present an exaggerated lumbosacral lordosis.

The patients who do not present a pelvic obliquity show an exaggeration of the lumbosacral lordosis. Their posture may be of the round hollow, round, or hollow types. The majority of patients present one of the first two types; the latter type is less common in its occurrence. A protrusion of the abdomen is usually seen and, when symptoms are acute, a mild spinal list of the sciatic type is not uncommon. Lumbosacral and sciatic-notch tenderness on one side or on both sides is usually a prominent subjective symptom. If the symptoms are acute at the time of the examination, tenderness of the entire superior gluteal region on one side or on both sides is found. In the patient presenting a round hollow back, anterior flexion of the lumbosacral spine is limited and manifested in the patient's inability to bend forward and to touch the toes with the knees

extended. Other spinal motions may or may not be limited, depending on the severity of symptoms at the time of the examination. Extension of the spine is usually painful, as is also lateral flexion to the affected side when symptoms are unilateral. Extension of the hips is frequently limited, due to short hip flexors. This is best demonstrated by the Thomas test with the patient's knees over the edge of the table and bent at right angles. Patients with short hip flexors also present taut iliotibial bands, as determined by the test recently described by Ober.

In those cases which present a fixed exaggerated lumbosacral lordosis, the straight-leg-raising test—extension of the knee with the hip flexed—will show evidence of hamstring limitation. This should not be interpreted as hamstring shortening. It is due to the fact that the posterior rotation of the pelvis has elevated the ischial tuberosity and increased the distance between the origin and insertion of the hamstring group. This fact can be readily demonstrated by making this test on a person who has the ability to roll the pelvis both forward and backward.

In cases of long standing, in addition to the findings mentioned, the segmental character of the disease may become evident, in that a hyperalgesia may be found over the sensory distribution of one fifth lumbar nerve or of both nerves. On two occasions, in addition to a sensory change in the fifth lumbar nerve, the author has found a hyperalgesia over the sensory distribution of the fourth lumbar nerve. In both instances, the roentgenograms revealed a marked settling, involving the third, fourth, and fifth lumbar intervertebral discs. The Achilles-tendon reflex is frequently sluggish in reaction and occasionally is absent.

Pathology

The pathology is practically the same as that found in patients suffering from the acute traumatic lesion,—that is, degenerative changes involving the annulus fibrosus and the nucleus pulposus. There is a subluxation of the facet articulations which results in degenerative arthritic changes. These patients more often present such findings in the lower lumbar articulations, as well as at the lumbosacral articulation, than do those suffering from the acute traumatic lesion. The neural pathology is undoubtedly the same; however, since symptoms are rarely as severe in this group, the opportunity of viewing it at operation is less frequent.

Roentgenographic Findings

The roentgenographic studies of those patients presenting a pelvic obliquity show a tilt of the sacral table, a narrowing of the lumbosacral joint space, a subluxation of the lumbosacral facets, and frequently hypertrophic lipping and sclerosis involving the facet articulations and, occasionally, the vertebral bodies. The roentgenographic studies of those cases which are due to a lumbosacral lordosis show a narrowing of the posterior margin of the lumbosacral joint space. A similar narrowing of the posterior portion of the intervertebral joint spaces continues through-

out the lumbar region. The subluxation of the facets, as well as the hypertrophic lipping and sclerosis, is most marked at the lumbosacral articulation and becomes less apparent as they approach the lumbothoracic spine.

Treatment

The treatment of patients suffering with chronic traumatic changes, due to a disturbance in postural mechanics, varies according to the age of the patient and the severity of the symptoms.

The patient who presents a pelvic obliquity should be compensated by adding a lift to the heel of the shoe. In addition to this, it is usually necessary to establish treatment along the same mechanical and reconstructive lines as is indicated in the patient suffering from a postural disturbance, due to an increased lumbosacral lordosis. For this reason, after the pelvic obliquity has been compensated, the patient is treated as any other postural case.

Men under the age of fifty and women under the age of forty who present an exaggerated lordosis of the lumbosacral spine, whose roentgenograms reveal narrowing of the posterior margins of the lower lumbar and lumbosacral intervertebral discs, and whose symptoms are not acute but low-grade and chronic in character are treated by postural exercises and instructions in positions. In addition, all evident foci of infection should be removed and high heels should be replaced by medium or low heels. In many cases it is necessary to make the change from high heels gradually, in order to avoid a severe acute foot strain. This is most liable to occur in the gouty type of individual who presents a round hollow postural deformity of the spine.

A patient of this type with an acute attack is treated in a plaster jacket. The cast is applied to the patient in the standing position with the spine flexed to such an extent that the lordosis of the lumbosacral region is eradicated. The jacket extends from the angle of the scapula to the midsacral region and is trimmed in front to permit right-angle flexion of the hips. The patient is then put to bed with the knees and the hips flexed for a period of from five to fifteen days, depending on the relief from symptoms. He then becomes ambulatory in the cast for a period of from three to five days, after which the cast is removed and an orthopaedic corset is substituted. As soon as all symptoms have disappeared, postural exercises are instituted and the use of the garment is discontinued. The patient is also instructed in positions and, if female, is advised to spend most of her time in shoes with a low or a medium heel.

In patients past the ages mentioned, unless they are unusually well preserved, the treatment differs in the following respects.

1. Postural exercises are instituted in order to restore muscle tone, but they are not carried out as strenuously as in the younger individual, due to the fact that a voluntary change in posture at this age period is a remote possibility.

2. Some form of fixation is necessary, in order to limit motion in the facets of the lumbosacral and lower lumbar articulations. In milder cases, an orthopaedic corset, extending from about the tenth thoracic vertebra down to the lateral gluteal folds, preferably with a pelvic band incorporated, will be sufficient. In more severe cases, it is necessary to support the lower spine with a brace which will eradicate the lordosis and which will at the same time afford immobilization. This brace is the same as that already referred to and will be described later.

The treatment of patients in this group who suffer an acute attack differs from that of the younger age group in that the garment or brace which is applied following the removal of the cast is worn either as a permanent form of fixation or for a period of time long enough to accomplish a natural fixation of the low spine. The postural exercises are instituted in this group to obtain muscle balance and not to bring about a voluntary postural correction.

Resistant cases which fail to respond to the most radical form of conservative treatment—the wearing of a flexion cast for a period of fifteen days or longer, followed by a corrective brace and postural exercises for a period of several months—should be treated surgically unless physical, mental, or economic conditions contra-indicate such treatment. Provided that symptoms are segmental in character, facetectomies, in addition to the fusion, should be done.

Postural Exercises

The success in changing a patient's posture through voluntary effort on his part depends to a large extent upon his understanding of the mechanical principles involved. For this reason, as a rule less effort is required in instructing a male patient. The physiotherapist should follow without variation the instructions of the clinician in every case. Patients should be warned against setting-up exercises as given through radio programs and popular magazines, due to the fact that such programs usually result in an active development of the spinal muscles which in our sedentary type of living are already overdeveloped as compared to their opposing groups.

It becomes evident from the principles already stated that a correct postural program should include: (1) an active development of the anterior abdominal, the gluteus maximus, and the hamstring groups; and (2) a passive stretching of the sacrospinalis and hip-flexor groups. Any exercise which calls into action the psoas or sacrospinalis muscles is liable to prolong, if not to increase, symptoms.

The indication for passive stretching of the hip-flexor or sacrospinalis muscles should be determined before the postural program is instituted.

Fixed posterior rotation of the pelvis and shortening of the spinal muscles can be determined by having the patient, with knees extended, bend forward and attempt to touch the toes. The same determination can be made by having the patient lie on his back with the hips flexed; the

operator then attempts to force the knees down to the axillae. Normally the pelvis will rotate forward, lifting the sacrum off the table, and the knees will contact the anterior axillary folds. In cases where there is a fixed posterior rotation of the pelvis this cannot be accomplished.

Shortening of the hip flexors can be determined by having the patient lie on his back on the table in such a position that the knees will be flexed to 90 degrees over the edge of the table. The hips are then flexed until the knees approximate the anterior axillary folds. The patient is then instructed to grasp tightly with both arms one knee and to extend completely the other hip. If the hip flexors are not shortened, the extended

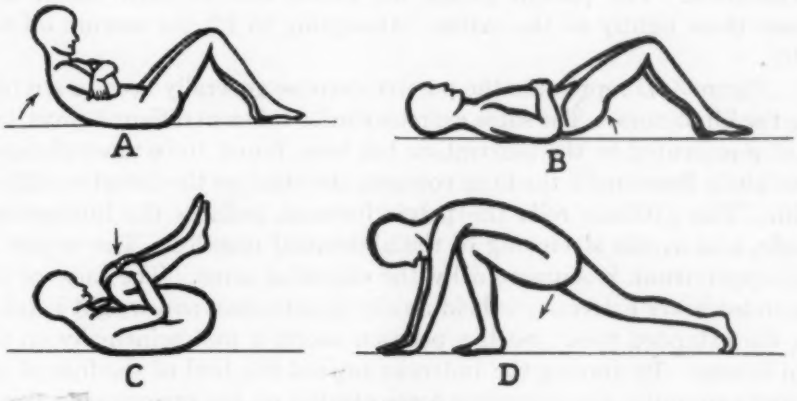

FIG. 3

Postural exercises designed to reduce the lumbosacral angle: *A*, active development of the abdominal muscles; *B*, active development of the gluteal and hamstring muscles; *C*, passive stretching of the sacrospinalis; *D*, passive stretching of the hip flexors.

thigh will contact the table without release of the hold on the opposite knee. This procedure is but a slight exaggeration of the Thomas test for flexion deformities of the hips.

Thin individuals who present the round postural type of back and hyperextended hips do not respond well to a postural program. Passive stretching of muscles is rarely indicated in this group. However, forced flexion of the lumbosacral spine should be done in those cases which show a fixed posterior rotation of the pelvis, due to pathological changes at the lumbosacral articulation.

The postural exercises which the author has used for the past two years with considerable satisfaction are shown in Figure 3.

Figure 3, *A* represents the exercise employed in developing the anterior abdominal muscles. The knees should be drawn up in order that the psoas muscles may not be called into action. The exercise in which the patient lies flat on his back and flexes the hips with the knees extended should not be given for developing abdominal muscles, due to the fact that the psoas action frequently aggravates symptoms.

Figure 3, *B* represents the exercise employed in developing the glu-

teus maximus and hamstring muscles. The pelvis is rotated forward by contracting these two muscle groups. The lumbar spine should remain on the table and the flexion should be accomplished at the lumbosacral articulation. The idea is best conveyed to the patient by telling him to "squeeze the cheeks of his buttocks together". The same exercise can be taken in a sitting position in an uncushioned chair. The buttocks should be slid forward to the front half of the seat and the pelvis rotated forward by contracting the gluteal and hamstring muscles.

Figure 3, *C* represents a passive exercise used in stretching the spinal muscles and in freeing the posterior fixation of the lumbosacral articulation. The patient grasps his knees, one in each hand, and draws them tightly to the axillae, attempting to lift the sacrum off the table.

Figure 3, *D* represents the passive exercise generally used in stretching the hip flexors. The same exercise can be taken in different ways, but that represented in the illustration has been found to be most effective. One hip is flexed until the knee contacts the chest at the anterior axillary fold. This attitude rolls the pelvis forward, reduces the lumbosacral angle, and avoids stretching of the abdominal muscles. The weight of the upper trunk is supported by the extended arms. The knee of the extended lower extremity is held rigidly in extension and weight is taken on the extended toes. Such a position exerts a pull principally on the hip flexors. By forcing the buttocks toward the heel of the foot of the flexed extremity, the stretching force exerted on the opposite hip flexors can be increased to any desired degree. Both groups of hip flexors can be affected by alternating the positions of the lower extremities.

This series of four exercises accomplishes an active development of the abdominal, gluteus maximus, and hamstring muscles, as well as a passive stretching of the hip flexors and sacrospinalis muscles.

The exercises outlined will accomplish a proper balance between the flexor and the extensor groups of postural muscles, but it is extremely important that the patient should understand the mechanics of the posture desired. Certain expressions such as "sit up straight", "throw your chest out", and "draw in your abdomen", should be stricken from our postural programs. The first statement results in protrusion of the abdomen and arching of the lumbar spine. The second causes the patient to force his shoulders back and to increase the lordosis, while the last results in his drawing up the diaphragm and holding his breath, which has nothing to do with posture.

The patient should be instructed to stand tall with the vertex (never the frontal region) of the head nearest the ceiling. The shoulders should be permitted to hang comfortably forward. The pubic region should be continuously lifted, and arching of the back should be avoided at all times. Posture should be checked against a vertical surface. With the patient's heels and calves against the wall, the lumbar spine should approximate the wall so closely that the hand cannot be passed between them. If it is

necessary to flex the knees to assume this position, further stretching of the hip flexors is indicated.

When the patient stoops or lifts, the pelvis should first be rotated forward and the floor then approached by flexing the hips and knees. The patient should never bend or lift with the knees extended. The load should be lifted by extending the hips and knees rather than the lumbar spine.

The sitting position should not be an attitude with the shoulders thrown back and the lumbar spine arched, but, rather, the lumbar lordosis should be eradicated and the entire spine should be a mild total curve with the concavity forward. This means that the patient should sit in a slightly slumped position and, when possible, the knees should be higher than the hips,—this is particularly true when riding in an automobile. A slumped position—that is, with the buttocks pushed slightly forward, the lumbar spine rounded, and the feet on a footstool—will usually permit a patient who otherwise might suffer severely to ride indefinitely without appreciable discomfort. If it is necessary to drive, the driving range should be shortened as much as possible, so that the knees are higher than the hips. In such a position, any jar is taken on the back of the sacrum and its force results in a widening of the lumbosacral foramina. On the other hand, if the force is taken in the erect attitude, it results in a constriction of the lumbosacral foramina.

Strenuous competitive athletics should be avoided by those who have a destruction of the lumbosacral intervertebral disc, for it is impossible under such circumstances to guard the positions of the low spine. Swimming is permissible, but diving should be avoided. Horseback riding by those who are sufficiently trained to take the jar on the extremities and to keep the abdominal muscles contracted is permissible. Ice skating frequently will relieve an attack of low-back pain; however, those untrained in the art may fall and thereby severely increase the symptoms. The carrying of a pack on the back is an excellent exercise for those suffering with this lesion, but the lifting and carrying of loads in front of the body should be avoided as much as possible for reasons which have already been given.

Patients suffering with this lesion should sleep with the knees and the hips flexed. This can only be accomplished on the back or on the side. They should be warned against sleeping on the abdomen as such a position increases the lordosis and aggravates the symptoms. In severe cases it is desirable to place a modern hospital bed in the home in order that such a sleeping position can be readily obtained. In other cases a roll placed under the mattress at the level of the knees will suffice. If the patient turns to his side during the night he will unconsciously draw his knees above the elevation and thereby maintain a satisfactory position.

It will be noted that the principles herein outlined are directed toward the restoration of those muscles which are sacrificed by the erect posture, and the restoration of the contour of the lower spine to resemble

as nearly as possible that of the quadruped animal. There are those who will object on the grounds that such principles are productive of round shoulders; however, it has been the author's experience that round shoulders are compensatory for an exaggerated lumbosacral lordosis. It will be a fortunate day for the "low-back" sufferer when school seats, stenographers' chairs, and chairs of all types are so designed as to discourage rather than to encourage a lordosis of the spine.

Lordosis Brace

The lordosis brace which the writer has used with satisfaction in these cases is so designed as to exert a constant corrective force. It permits free anterior flexion, but prevents extension and lateral flexion of the lumbosacral spine. There are three principal points of pressure,—the thoracic spine, the sacral spine, and the lower abdomen. The brace shown in Figure 4 is to a considerable extent self-explanatory. The

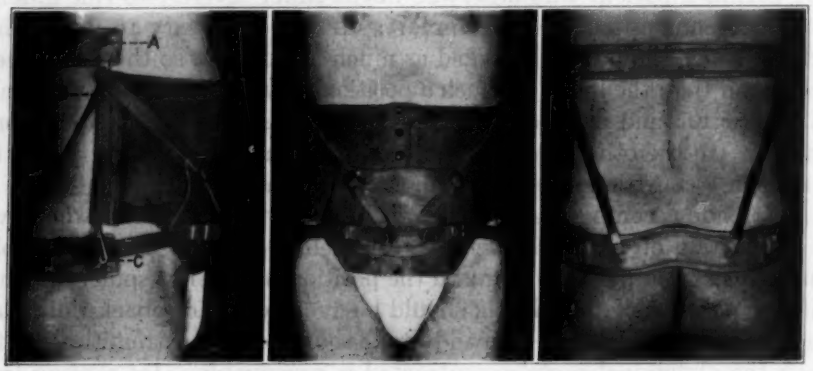

FIG. 4
Lordosis brace. Three-point-pressure principle.

dorsal and sacral bands are made of thin flexible steel covered with leather. The uprights attached to the sacral band hinge at *B*. The upper strap, which buckles to the abdominal pad, is only a stabilizing strap for the dorsal band and should not be drawn too tight. The lower strap, which is attached to the lower end of the upright *ABC*, furnishes the corrective pull. This strap passes through a ring attached to the sacral band, then forward under upright *ABC*, and fastens by a buckle to the abdominal pad. The abdominal support which lies under the abdominal pad is made of perforated pure rubber known as "acid packing". It fastens in the midabdominal line by means of snaps similar to those used on the wrists of leather gloves.

CONCLUSIONS

In concluding this phase of the discussion of lesions of the lumbosacral spine, which deals only with destruction of the intervertebral disc, the author wishes to add that lumbosacral fusion is not a panacea for all

low-back troubles. In his experience it has afforded relief from symptoms in those patients who suffered only from a traumatic destruction of the lumbosacral intervertebral disc, and who had not experienced segmental symptoms. Lumbosacral fusion, combined with facetectomy, has given relief to those who suffered only from a traumatic destruction of the lumbosacral disc and who had experienced segmental symptoms.

Surgery should never be employed until a thorough conservative program has overcome a fixed lumbosacral lordosis and lengthened the short hip-flexor muscles. If this is not accomplished preoperatively, the patient will be liable to develop symptoms just above the graft a few months after becoming ambulatory. It has been the writer's experience that a well-planned conservative program will eliminate the need for surgery in most cases.

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SACRO-ILIAC FUSION

BY F. A. BLOOM, M.D., HOUSTON, TEXAS

The purpose of this paper is to present a new method for fusion of the sacro-iliac joint. The method which the author has devised differs from the classical Smith-Petersen operation in the approach and in the manner in which the plug is removed from the ilium. As far as the writer has been able to find out, from a search of the literature, this particular procedure is new.

The operation begins with the usual preparation of the skin prior to any orthopaedic procedure. The patient is draped in the prone position. The anaesthetic may be either spinal or general. A line is drawn on the skin from the anterior superior spine to the posterior superior spine of the ilium. At a point on this line, one and one-half inches anterior to the posterior superior spine, a perpendicular is dropped downward for half an inch.

An incision, three to four inches in length, is then made in the direction of the fibers of the gluteus maximus, the center of the incision coinciding with the lower end of the perpendicular line. The incision extends down through the skin and fascia to the muscle. The palpating finger then splits the muscle fibers and is carried down until the superior border of the greater sciatic notch is defined. With the finger as a guide, a Steinmann pin, three-sixteenths of an inch in diameter and eight inches long, is then passed down through the muscle fibers to a point on the ilium, one inch superior to the upper border of the greater sciatic notch. It will be found that this point will coincide with the center of the incision.

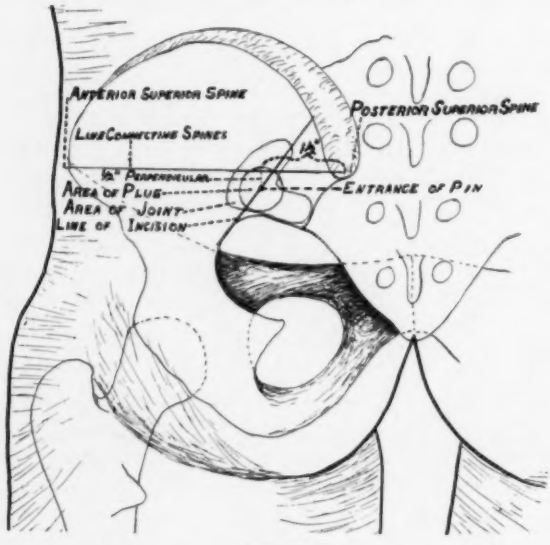

FIG. 1

Diagrammatic representation of the field of operation.

The pin is then driven into the outer table of the ilium perpendicular to the surface through which it passes. By driving the pin slowly with a small hammer, an increase in density can be detected when the pin strikes the joint. The pin is driven approximately one-half an inch after it passes through

the joint line. Blunt dissection will enable the operator to expose a small area of the ilium at the base of the pin. Two retractors with blades, four inches long and two inches wide, are inserted above and below the pin. These easily expose the area of bone at the point of entrance of the pin into the ilium. A hole saw, one and one-quarter inches in diameter, attached to a fenestrated shaft, is passed over the pin down to the ilium. A standard Hudson surgical brace is then fitted to the shaft of the saw and a circular piece of bone is cut. If the cutting is done slowly, it is easy to determine when the saw passes through the joint line. The cutting is continued until the saw is a quarter of an inch into the sacrum,—that is, through the joint line for a quarter of an inch. After this has been done, the saw and the pin are removed.

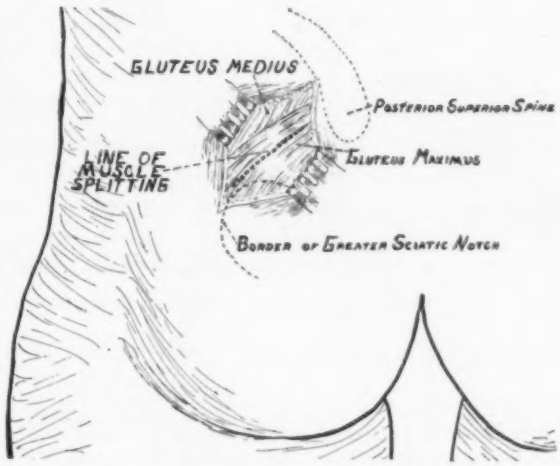

FIG. 2

Skin and superficial tissue retracted, showing the muscle fibers and the line of the muscle splitting.

Usually the plug of bone will be loosened sufficiently to come out with the saw. If not, the plug can be easily loosened with a periosteal elevator, or with a large gouge, by a simple prying motion through the cut. At times the plug may include both the iliac and the sacral portions of the joint. On the other hand, it may include only the iliac portion. If the sacral portion is not loosened, it is necessary to remove the cartilage from this piece by means of a large curette or gouge, taking care that all of the sacral cartilage and cortical bone are removed. If both portions of the joint

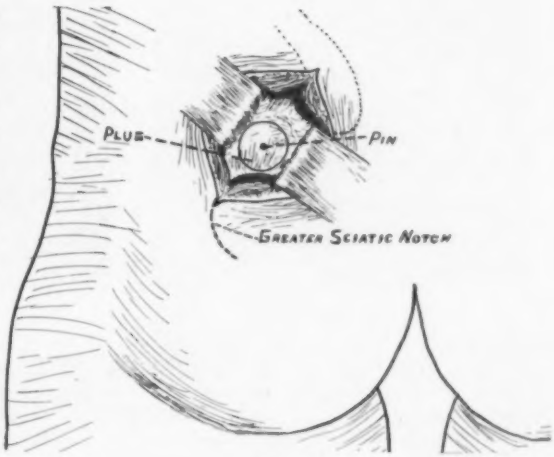

FIG. 3

Muscle retracted, exposing the lateral aspect of the ilium. The point of insertion for the pin and the area of the plug are indicated.

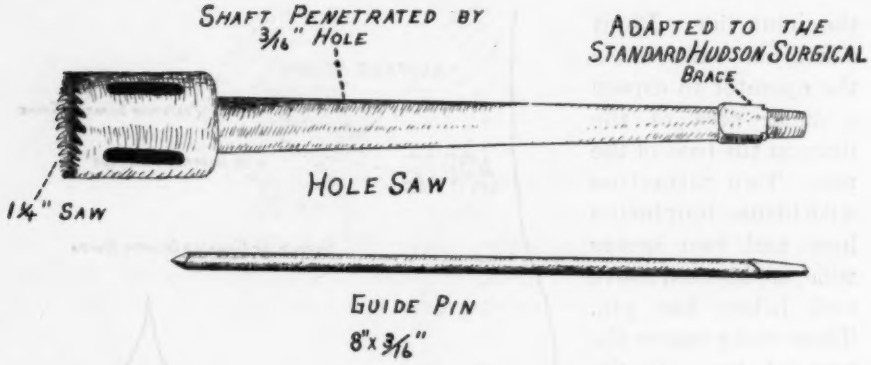

FIG. 4

Drawing of the hole saw used for cutting the plug. The saw is one and one-quarter inches in diameter. The shaft is pierced throughout its length by a hole, three-sixteenths of an inch in diameter. The small end of the instrument is shaped to fit a standard Hudson surgical brace.

come out as a plug, these two pieces are separated through the joint line and the cartilage is removed from each. The denuded plug is then replaced in the hole and wedged tightly by means of a slight impaction. The wound is closed in the usual manner. Both joints can be fused by the method described in from fifteen to twenty-five minutes, including closure of the skin, without any undue haste.

No immobilization of any kind is applied. The sacro-iliac joint has been approached in such a manner that none of its supporting structures have been weakened and the author sees no more reason for support following the operation than before the operation was performed. Since the plug is impacted through the joint line, it forms a graft, about one and

FIG. 5

FIG. 6

FIG. 5:

A Steinmann pin, three-sixteenths of an inch in diameter and eight inches in length, is seen driven through the sacro-iliac joint of a mounted pelvis. The plug has been cut with the hole saw. The relationship of the plug to the greater sciatic notch is well demonstrated.

FIG. 6:

The cut plug of the ilium has been removed and remains transfixed by the pin. The cartilage of the sacral side of the sacro-iliac joint can be seen within the hole in the ilium.

one-quarter inches in diameter, across the joint, and bony union takes place rapidly.

Following this operation, the patients have little or no surgical shock. They usually feel quite well on the next day and need no opiates or other pain-relieving drugs. The patients are permitted to sit up as soon as they desire,—usually in from three to four days. Unless other factors contra-indicate, the patients are allowed out of bed without restriction in fourteen days.

The operative procedure described has been carried out on four patients. The following are summaries of these cases.

CASE 1. H. C., negro, male, thirty-eight years old, a laborer, had had constant pain in the back for eighteen months.

Diagnosis: Bilateral chronic hypertrophic arthritis of the sacro-iliac joints.

Treatment and Follow-Up: On August 22, 1936, both sacro-iliac joints were fused. On September 6, 1936, the patient was discharged from the hospital, walking. Check-up roentgenograms, on October 25, showed bony union about the plug in both joints. Clinical tests for sacro-iliac pain were negative. The patient stated that he was greatly improved, but he did not feel that he was able to return to work. The author has been unable to locate the patient since October 25, 1936.

CASE 2. A. C., white, male, forty-two years old, a laborer, had spondylolisthesis of four years' standing with partial spastic paralysis of the lower extremities.

Diagnosis: Disuse atrophy and relaxation of the sacro-iliac joints.

Treatment and Follow-Up: On September 12, 1936, both sacro-iliac joints were fused. Postoperative recovery was uneventful. On December 14, 1936, check-up roentgenograms showed solid bony union across both sacro-iliac joints. No true sacro-iliac pain could be demonstrated clinically. The patient was greatly improved, but still complained of some pain in the region of the right sacro-iliac joint.

CASE 3. J. D., white, male, fifty-two years old, a laborer, had had pain in the back for the past twenty years. Two years prior to admission to the hospital, the patient had lifted a heavy object and had been unable to work since that time.

Diagnosis: Hypertrophic arthritis and sprain of the right sacro-iliac joint.

Treatment and Follow-Up: On November 4, 1936, both sacro-iliac joints were fused. Postoperative recovery was uneventful. The patient was dismissed from the hospital sixteen days following the operation. On January 20, 1937, roentgenograms showed a firm union at the site of the arthrodesis on the right. Union of the left joint was also present, but not as complete. The patient stated that he was greatly improved. Tests for sacro-iliac pain were still slightly positive on the right. The tenderness on pressure over the right sacro-iliac ligaments had completely disappeared.

CASE 4. W. W., white, female, thirty-eight years old, had had constant pain in the right thigh for three and one-half years.

Diagnosis: Sacralization of the fifth lumbar vertebra on the right. Right sciatic neuralgia.

Treatment and Follow-Up: On November 28, 1936, the lumbosacral joint was fused by a graft from the ilium. Both sacro-iliac joints were fused, and the sacralized process was excised. The patient was then placed in a plaster jacket. This patient was immediately and completely relieved of the sciatic pain, probably due to the removal of the sacralized process. On February 17, 1937, the jacket was removed and the patient was allowed to get out of bed wearing a back brace. Roentgenograms showed good union across both sacro-iliac joints.

In all of the cases cited, there was both clinical and roentgenographic evidence of bony union of the sacro-iliac joint in three months following

the operation, and in no case was there evidence of non-union. In Case 4, the operation on the sacro-iliac joints was done as an additional stabilizing procedure in a congenitally malformed back, with the hope that future trouble might be avoided.

ADVANTAGES

1. Fusion of the sacro-iliac joint is done through a small incision and with less dissection than in other methods.
2. The time consumed in completing the operation is diminished.
3. The bone plug is removed accurately from a predetermined site which is fixed by the pin from the outside, before extensive dissection obscures the field.

DISADVANTAGES

The operation has been done upon two joints of a mounted pelvis, six joints in cadavera, and eight joints in living patients. The author has as yet found no disadvantage. The possibility of driving the pin too far has been considered; however, a rather wide range of safety is left after the pin passes through the joint. The pin must pass about one and one-half inches past the joint line before any real damage can be done. This can be avoided by using a moderate amount of care in inserting the pin. The possibility of cutting the plug too deep is rather remote, since the hole saw is not of sufficient length to allow this to happen.

CONCLUSIONS

1. A bone plug, one and one-quarter inches in diameter, can be removed through the sacro-iliac joint by the method outlined.
2. Bony fusion of the sacro-iliac joint can be brought about by the procedure described.
3. As performed by the author, the operation for fusing the sacro-iliac joint is made simpler and causes less reaction in the patient than other methods used.

CONSERVATIVE THERAPY FOR FRACTURE OF THE OS CALCIS*

BY OTTO J. HERMANN, M.D., BOSTON, MASSACHUSETTS

The most common variety of fracture of the os calcis is that in which there is a rather formless comminution of the bone as a whole,—the bone is broken through near a vertical plane, just in front of, or commonly through, the posterior articular surface between the astragalus and the os calcis, with a lateral broadening ("piling up") and pushing up of the posterior part of the heel. It is with this type that this paper is concerned.

At the Boston City Hospital, for the past thirty years, we have proceeded along conservative lines of treatment of this fracture, trying out, rejecting, and retaining innovations both in the initial treatment and in the after-care. For example, in the early 1920's we used continued traction with tongs, and later, in 1928, continued Kirschner-wire traction. We discarded these innovations when, despite careful initial technique, asepsis and follow-up, sepsis developed in almost 10 per cent. of the cases. This we know can be devastating and crippling in such a cancellous bone as the os calcis. This experience inclined us to conclude that foreign-body traction through a traumatized area is surgically unsafe and unsound.

Our most radical and important modifications came in our after-care of these fractures. Here we discovered that our greatest bugbear, the repiling up of bone in the submalleolar areas, was checked by constant snug pressure maintained over a period of from ten to twelve weeks. We gradually worked out our definite routine after-care whereby we checked this excess new callus formation while the foot was in plaster fixation and during the first six weeks following the removal of this plaster cast. We finally adopted the following steps which we now use in our treatment of fractures of the os calcis of the crushed type.

PRELIMINARY TREATMENT

1. Roentgenograms are made upon admission, a lateral and an axial view of both heels being taken. The films of the uninjured heel are used as a comparison for measurements of the injured one and also to detect any bone anomalies that might complicate the interpretation of the fracture. The axial view is made as follows: a strip of two-inch roller bandage is placed in a loop about the anterior arch of the foot with the ends held by the patient; the foot is drawn into moderate dorsiflexion; the film is placed underneath the heel and the lower leg; and, finally, the axis of the x-ray tube is directed onto the plantar surface of the heel at an angle of 45 degrees. In severe cases, a third view is taken in an effort to see more clearly the subastragalar joint. Since compression fractures of

* Presented before the Meeting of the Fracture Committee, American College of Surgeons, Boston, Massachusetts, January 15, 1937.

FIG. 1

Operating kit: a rolled sterile towel, a weighted seven-pound wooden mallet, a scalpel, the sawed-off upper end of a crutch, tongs, Forrester clamp, a sterile covered sandbag.

the lower spine occur not infrequently with os-calcis fractures (in about 10 per cent. of our cases) routine lateral and anteroposterior roentgenograms of the lower thoracic and lumbar vertebrae are made to rule out such fractures. This procedure has been adopted by us so that no such lesion will be inadvertently overlooked. There have been patients with fracture of the os calcis, complicated by spine fracture, who did not complain of any back discomfort. Therefore, such a roentgenographic check-up of the spine is now the rule in our first examination. From the roentgenograms of the os calcis the surgeon learns the exact amount of lateral expansion, the comminution present, the condition of the astragalocalcaneal joint, the salient angle or angle of incidence, the location of the vertical and longitudinal fracture lines (one must plot these lines so as to avoid them in the placing of ice tongs during reduction), the condition of the sustentaculum tali, and, finally, the existence or

FIG. 2

Patient turned on side opposite injury. The sandbag is placed under the inner side of the injured heel. A sterile rolled towel is placed beneath the external malleolus. Then, with solid heavy blows, impaction is broken up and the piled-up bone beneath the external malleolus is pounded down.

non-existence of subluxations between the os calcis and the cuboid, or between the astragalus and the scaphoid.

2. The emergency treatment is very simple,—the foot and lower leg are encased comfortably in a "pillow and sides" splint with appropriate bleb dressings and an ice bag if deemed necessary.

FIG. 3

This illustrates how easily the thumb can be pressed into the depression beneath the external malleolus and the heel can be molded by the fingers after the pounding.

3. A one or two-day "bone prep" is given as soon as the acute local reaction has subsided, which may be from one to ten days.

REDUCTION AND FIXATION

1. The operating kit (Fig. 1) consists of a tightly rolled sterile towel, a sandbag with a sterile cover, a seven-pound large wooden mallet, a pair of bone tongs, the Forrester bone clamp, a sawed-off crutch, a scalpel, a sterile dressing, and two rolled pieces of felt bound by adhesive (four inches by one and one-fourth inches). Besides this kit, there is the usual sheet-wadding and plaster-of-Paris bandages.

2. Local anaesthesia is never used. Generally a light-dosage low spinal anaesthesia, or a gas-ether anaesthesia, is employed.

3. The technique is as follows:

The patient is turned on the side opposite the injury and a sandbag is placed under the inner side of the heel. The tightly rolled towel is placed beneath the external malleolus and then,

FIG. 4

With a scalpel, small incisions are made about an inch or so above the apex of the heel. The tongs are driven in and locked, and traction is then made in a rotary fashion, beginning downward and swinging upward, with counter-traction exerted just proximal to the cuboid joint.

FIG. 5

The os calcis is remolded systematically from the external malleolus downward by means of the Forrester clamp. Again traction is exerted downward and upward with counterpressure in the os-calcis and cuboid areas.

with solid heavy blows, the piled-up bone beneath the external malleolus is pounded down until the normal depression beneath the external malleolus is restored. (See Figure 2.) Roughly, we gage it by placing the thumb in this depression and, if the thumbnail is on a level with the outer surface of the external malleolus, we are satisfied. This procedure we have named "disimpaction". Offhand it would seem that such heavy pounding would cause terrific bruising of the tissue, with resulting necrosis. This is not so. In only one case did we get any degree of pressure necrosis and that was in a case in which we did not wait until all the acute local traumatic reaction (swelling, etc.,) had subsided and in which there was insufficient padding. We believe the tightly rolled towel with the broad-faced mallet precludes such damage.

The heel is quickly molded by hand (Fig. 3), and the various motions are tested. The testing of motions, particularly the lateral, is important. It has been pointed out that by doing this we may lose our reduction in part or in whole. If we do not test, we will not know whether there still exists a submalleolar bone block, and whatever is lost at this stage in the reduction is regained immediately by the traction and remolding.

FIG. 6

Small sterile dressings are first placed in the two stab wounds in the heel and then on the dressings is superimposed a snug roll of felt, four by one and one-quarter inches, placed horizontally beneath each malleolus.

With the scalpel, small stab wounds are then made in the upper posterior part of the heel (care being taken that no fracture lines are entered, these having been previously located by x-ray). The tongs are driven in and locked, and with countertraction from the crutch, which has its handle resting against the operator's abdomen

or chest and the cross-bar of the sawed-off end resting against the sole of the foot in the line of the calcaneocuboid and the astragaloscaphoid joints, lusty traction is made in an arcwise fashion. (See Figure 4.) This pull begins in a downward and outward direction and, with well-sustained traction, it is carried upward and toward the operator. This type of pull was adopted to overcome the posterior vertical pull of the calf muscles through the tendo achillis and the inferior horizontal pull by the intrinsic muscles of the foot. It is here that the value of the preliminary disimpaction is felt,—the large posterior fragment can be pulled down, whereas, if it were left impacted, only a long-continued traction could do this.

FIG. 7

A low plaster-of-Paris cast is finally applied with the foot somewhat inverted and in plantar flexion. While this cast is hardening, pressure is brought to bear over the pads.

The tongs are now removed and the heel is remolded by the use of the Forrester bone clamp (Fig. 5). When the desired compression has been obtained by this clamp, the traction is again applied through the clamp. The entire heel is carefully and systematically molded in this fashion.

The heel is now again examined manually. (At this point we are henceforth to make our check-up roentgenograms, for we have found that check-ups through a plaster cast are quite unsatisfactory.)

Tightly folded sterile dressings are placed over the stab wounds in the heel and held in place by a sterile gauze strip wound about it. A snug roll of felt, four inches by one and one-fourth inches, is now carefully placed at a very slightly oblique angle beneath each malleolus. (See Figure 6.)

A low plaster-of-Paris cast is then applied with the foot in slight inversion and in extreme plantar flexion. While this cast is hardening, manual pressure is applied over the pad areas. (See Figure 7.)

AFTER-CARE

1. The first cast is removed in two weeks. The submalleolar pads are carefully replaced and, with the foot at right angles, a new cast is applied.

2. A new cast and pads are applied every two weeks up to ten or occasionally twelve weeks. We do this so as to maintain constant snug pressure beneath the malleoli, and it gives us a chance to check up on local conditions. (This constant localized pressure has taught us, during the past decade and more, that such pressure surely retards callus formation and, consequently, we have been very careful in the placing of corrective pressure pads or appliances in other types of fractures.)

3. After removal of the last cast, the special ambulatory os-calcis splint (for which the patient has been measured just before application

FIG. 8-A

FIG. 8-B

Lateral and axial views, taken on admission.

of this cast) is applied at once. This immediate application of the brace is important, since the pressure pads will be more effective than if applied later when oedema is present.

4. Daily massage, active foot and ankle motions, gradually increasing toe and heel and foot-rocking exercises, supination plank-walking, and radiant heat or hot soaks are also begun after removal of the last cast.

5. Full weight-bearing without crutches, but with an ambulatory splint, is begun ten days or two weeks after omission of the last cast. By that time, the foot, ankle, and leg muscles should have regained their lost tonicity by the daily physiotherapy routine. Greater comfort during the beginning of this weight-bearing period may often be obtained by a one-sixth-inch Thomas heel and a well-fitting inner sole with a pocket for anterior and plantar arch pads.

6. At the end of another six weeks (four and one-half months following initial reduction), the ambulatory splints are gradually discarded, and the patient is instructed as to more strenuous foot exercise and increased walking on rough surfaces. It is during the early part of the direct-weight-bearing period that careful record is made of the patient's pain symptoms. If the patient complains of persistent pain in the affected subastragalar-joint region, and the original fracture was of the intra-articular type and comminuted, then and then only do we consider fusion of the subastragalar joint. In the rare case, where there was originally marked subluxation in the calcaneocuboid or astragaloscaphoid joints, which has not been wholly corrected, and the patient has definite pain there, a triple arthrodesis is considered. Again, where there is definite pain in the tendo achillis, a lengthening of that tendon is considered.

FIG. 9

Postreduction axial views.

Where there is submalleolar-impingement pain, due to a repiling-up beneath the external malleolus, the so-called "scoop" operation is con-

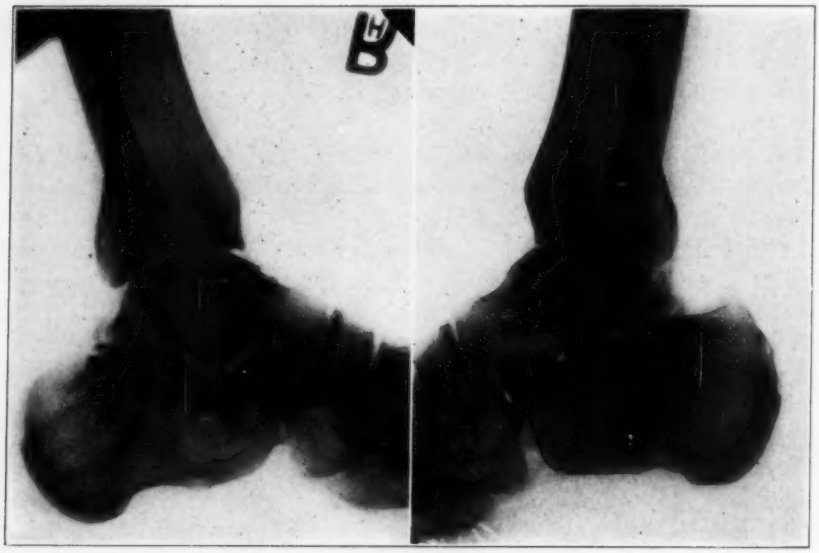

FIG. 10-A

Lateral views taken fifteen months later.

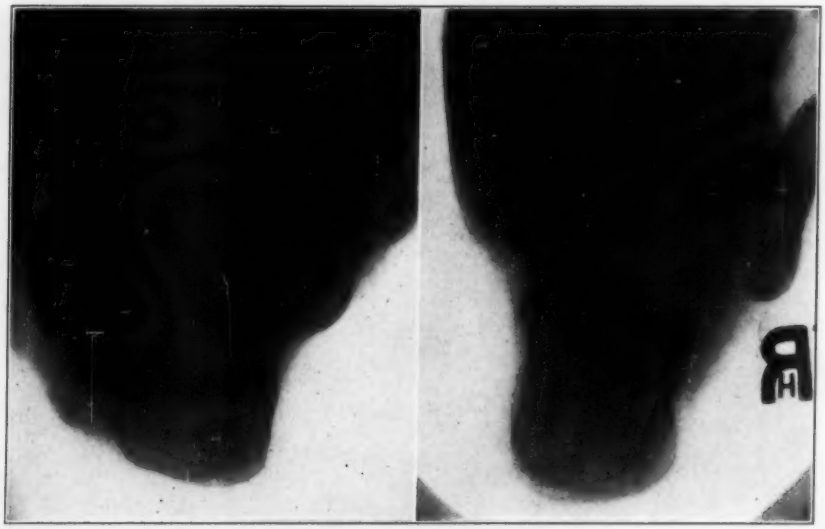

FIG. 10-B

Axial views.

J. J. Roentgenograms showing bilateral fracture of the os calcis. The patient is a painter who dropped fifteen feet from a ladder, striking on both heels. The os calcis was molded and put in fixation and the patient was given the routine treatment. He was back at part-time work in five months and at full-time work in six months. There was absolutely no loss of motion, nor any local complaint of pain, especially in regard to the involved joints.

sidered. Finally, in the very exceptional case, where the heel has been drawn up markedly and has not been successfully pulled and held down, giving a resulting flat (or worse) heel, a "Gleich" operation is considered.

END RESULTS

The results in our latest series of cases were based on an accurate study of the progress of every patient over a period varying from six months to five years. In this series we have taken into account only those to whom we gave both initial treatment and after-care. The total number of such patients was 171 and of these we have excluded the following: twenty-six who did not return to us following the initial reduction, practically all of whom were taken in hand by the various insurance clinics; six not originally treated by us and whom we arthrodesed or "scooped" early; eight who have not yet had four months of treatment. Among the 131 remaining, there were twenty-one with bilateral fractures of the os calcis, which makes a total of 152 acute fractures of the os calcis, of the type mentioned earlier in this paper, that were treated by this method and were under our supervision during convalescence. The end results were classified as: "good", "fair", and "poor". (See Table I.)

TABLE I

END RESULTS IN 152 CASES OF FRACTURE OF THE OS CALCIS

Result	Cases	Per Cent.
Good	111	73
Fair	21	14
Poor	20	13
Total	152	100

The patients in the "good" class are those who, by the sixth or seventh month, had regained full functional use of the injured heel and had no pain or discomfort at any point of the heel after normal activity. That means that there was no submalleolar-impingement pain due to a submalleolar "piling-up", no subastragalar-joint pain, no tendo-achillis discomfort, no plantar or anterior-arch pain, no disturbance in the calcaneocuboid-joint areas, no painful "spur" formations. All such "good" cases need not necessarily have had Grade A anatomical reductions. The "fair" division includes those patients who required seven to eighteen months to return to the normalcy just described.

The "poor" group includes those who, during the first three to four weeks of weight-bearing, had persistent pain in the subastragalar joint, in the calcaneocuboid or astragaloscaphoid-joint areas, about the tendo achillis, or in the submalleolar region. These were the patients upon whom we generally did a subastragalar arthrodesis. (In only one case were we obliged to do a lengthening of the tendo achillis, and in only one case did we do a "Gleich" operation.)

CONCLUSION

The real advance which we have made in our conservative treatment of fracture of the os calcis is in the after-care. We believe our reduction and molding method is quite simple, safe, efficient, non-destructive, and easily mastered. Our routine after-care maintains the initial reduction and molding and prevents the formation of excess callus (especially in the submalleolar region), with its painful and crippling sequelae. It provides the specially placed, constant, snug pressure which we have found essential for a good end result. Finally, we hope that by our work we have demonstrated that routine initial destructive operative procedure should not be adopted in treating fractures of the os calcis. This and other special operations should be reserved for selected cases,—those cases in which the conservative treatment alone is not effective.

The author wishes to acknowledge his indebtedness to Dr. Harold M. Childress for his help in examining the records and in studying the cases which have been considered in the preparation of this paper.

UNUSUAL LOCATIONS OF TUBERCULOUS LESIONS IN THE SPINE

BY Z. B. ADAMS, M.D., BOSTON, MASSACHUSETTS, AND JOHN J. DECKER, M.D., MIDDLEBORO, MASSACHUSETTS

From the Lakeville State Sanatorium, Middleboro, Massachusetts

Since the opening of the Lakeville State Sanatorium for the treatment of surgical tuberculosis in 1910, there have been 470 patients with tubercu-

FIG. 1

Roentgenogram of an adult male, twenty-five years of age, with tuberculosis which originated in the intervertebral disc. The disc and the upper and lower plates of the adjacent centra have been destroyed, but the centra have not collapsed. This type occurs in children as well as in adults.

FIG. 2

Tuberculous disease in a girl, aged thirteen. The destructive process originated in an intervertebral disc in the lumbar spine. The roentgenogram also reveals extensive involvement of the thoracic spine with invasion of the disc in the two lower bodies. The other diseased thoracic bodies show the ordinary tuberculous involvement of the centra.

FIG. 3

Roentgenogram of an adult female, aged twenty-six, showing tuberculosis of anterior upper edge of the third lumbar centrum and slight narrowing of the intervertebral disc. Such cases have been thought to be malignant metastases until proved to be tuberculosis by material from an abscess.

FIG. 4

Roentgenogram of a girl, aged nineteen, showing destruction of the left lateral lower edge of the second lumbar vertebra. The disc is still present but thinned. A bone-graft was used with good results.

FIG. 5

Roentgenogram of an adult male, aged twenty-four, showing tuberculosis of the lower part of the second lumbar body. The disc still persists. The anterior wall of the third lumbar body is being absorbed.

FIG. 6

Adult male, aged fifty-three, with tuberculosis of the fourth and fifth cervical vertebrae. The roentgenogram shows narrowing of the disc and of the anteroposterior diameter of the bodies, no collapse of vertical height, and a retropharyngeal abscess. Tuberculous organisms, as well as bilateral tuberculous epididymitis, were found. The patient was treated for ten years in the Sanatorium with a leather collar.

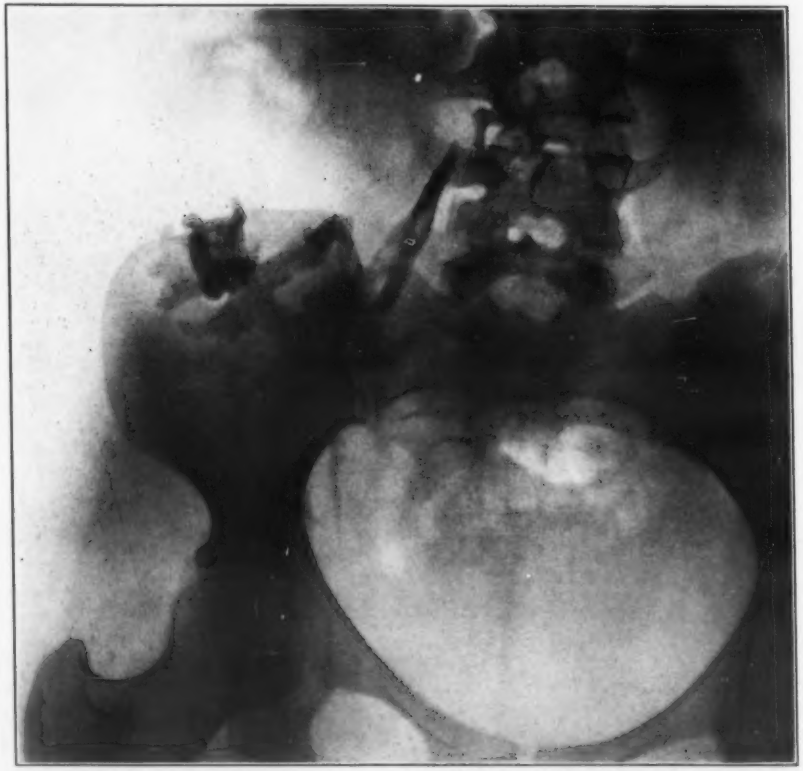

FIG. 7

Roentgenogram of a girl, sixteen years old, showing destruction of the inferior articular process of the third lumbar vertebra and of the superior articular process of the fourth lumbar vertebra on the right. Bismuth paste, injected into the sinus, filled the abscess and led up to the diseased joint. Tubercle bacilli were found in the discharge.

FIG. 8

Roentgenogram of the spine of a child, eleven years of age. The third and fourth lumbar bodies have collapsed and are fusing into a bony mass. Note that the posterior portions of the three bodies above this mass have degenerated areas with a small sequestrum in each. There is no collapse of these bodies, although the discs are somewhat thinned. An Albee bone-grafting operation was done in this case and subsequent roentgenograms show that these areas are filling in.

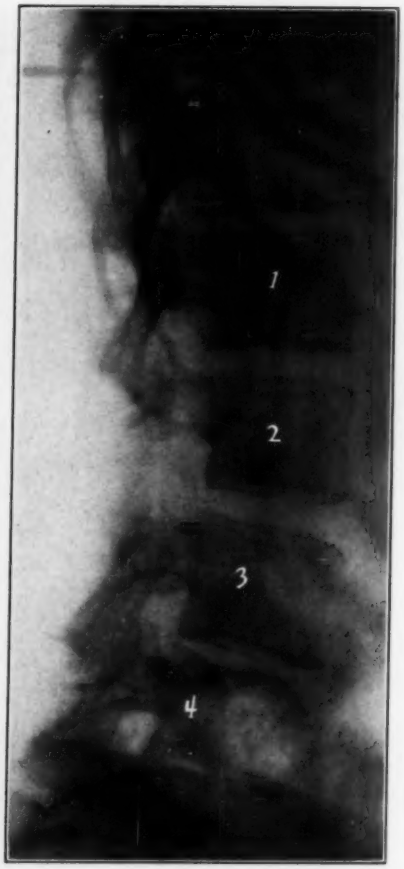

FIG. 9

Lateral roentgenogram of a colored female, aged thirty, showing tuberculosis of the spinous process of the second lumbar vertebra with destruction of the lamina and articular processes. Other foci were present in the bones and tubercle bacilli were found. There have been three similar cases, two of which were mistaken for malignancy.

losis of the spine admitted for care and treatment. Consequently an unusual opportunity has been afforded for studying the severe types of spinal tuberculosis and the end results of treatment. The accompanying roentgenograms, selected from these cases, illustrate the locations of the primary focus in the vertebrae and the character of the destructive process.

The usual site of the destructive lesion is the anterior part of the

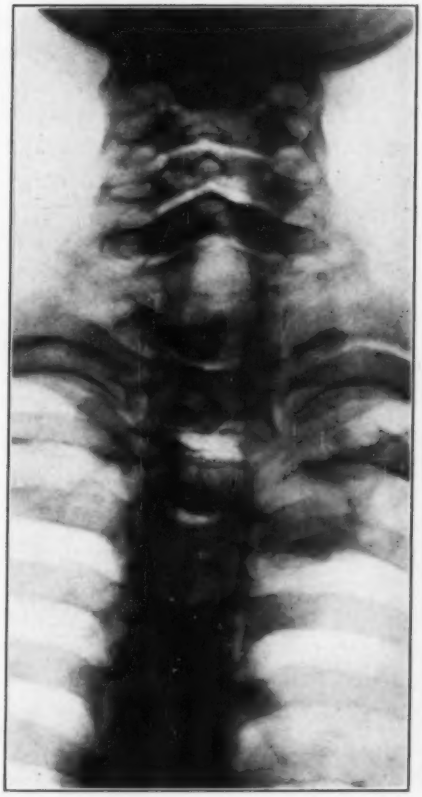

FIG. 10

Roentgenogram of a boy, aged fifteen, showing destruction of the head and neck of the third rib on the right and of the spinous process, lamina, and transverse process of the first thoracic vertebra. As in the case shown in Fig. 9, this case was first thought to be malignant, but later tubercle bacilli were recovered.

FIG. 11

Roentgenogram of a boy, ten years old, showing involvement of the head of the twelfth rib on the left. There is no narrowing of the disc, but a slight destruction of the left lateral wall of the twelfth centrum can be seen. There is no other tuberculous bony focus in the spine. Autopsy disclosed an abscess encircling the column of the centra from the seventh thoracic vertebra to the first lumbar vertebra.

centrum. Two or three adjacent vertebrae may be simultaneously affected. The process seems to spread up and down under the anterior common ligaments, infecting the centra above and below.

There are certain cases, usually in the low thoracic or lumbar region, in which the disease focus originates in the intervertebral disc and completely destroys the disc and the upper cortical plate of the centrum below and the lower cortical plate of the centrum above. (See Figures 1 and 2.) This type occurs both in children and in adults, and in children goes on to rather rapid healing without operation. In adults a fusion at the back is usually done, followed by support in a double spica jacket. About twenty cases of this type have been observed.

In the usual type, the destructive process destroys the anterior portion of the centrum and the discs intervening, as demonstrated in the mid-thoracic region of the spine shown in Figure 1. Occasionally, only the anterior portion is decalcified (Fig. 3) or the process may destroy one side of the centrum, causing a lateral deformity of the spine (Fig. 4). In some cases, the lower half of the centrum may be destroyed, and the disc persisting pushes upward into the softened bone (Fig. 5).

An example of the type in which the disease spreads under the anterior common ligament is shown in Figure 6. The disc is thinned, the anteroposterior diameter is diminished, and there is no collapse. In this case, the disease healed after ten years of treatment in the Sanatorium with head support but without operation.

The articular joints are very rarely the primary site of the tuberculous lesion. Figure 7 shows the only case that occurred in our entire series. The right articular joint beween the third and fourth lumbar vertebrae has been partially destroyed, and both bony processes show erosion.

Figure 8 illustrates cavity formation with small sequestra in three of the bodies; these sequestra are slowly absorbing after seven years of sanatorium treatment combined with an Albee bone graft.

Three cases have been observed at this hospital in which the tuberculous destruction originated in the spinous process. (See Figures 9 and 10.) This location of the disease contra-indicates the use of a bone graft because of the presence of pus in the operative area. These cases are of further interest because of the fact that two of them were mistaken clinically as well as roentgenographically for malignant disease.

In four of our cases, the tuberculous lesion was situated between the head of the rib and the vertebral centrum. (See Figure 11.) This location also complicates the problem of treatment.

It must be recognized that the roentgenogram does not always give positive evidence, for, at autopsy, vertebral centra are often found to be completely infiltrated with tuberculous material when previous roentgenographic examination has given no evidence of the disease.

OSTEOGENESIS IMPERFECTA

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Osteogenesis imperfecta is a disorder of bone formation in which increased fragility is the most important manifestation. The etiology is unknown. Key and Kersley believe that this disorder is due to "congenital instability of the mesenchyme". Weber's studies led to the conclusion that the functional location in this disorder is in the walls of the blood vessels and the composition of the intercellular substances. Kraus, and Wyatt and McEachern found evidence of changes in the glands of internal secretion. The deranged metabolism is poorly understood.

We have had the privilege of treating and studying, over a period of more than two years, a patient found to have osteogenesis imperfecta. A report of this case follows.

The patient is a female white child. Her birth at Jefferson Hospital was spontaneous and normal, and she was bottle-fed. The birth weight was six pounds and four ounces. On the sixth day a deformed left thigh was discovered. Roentgenographic examination revealed a fracture of the femur. Four other fractures, including a stellate fracture of the skull, occurred during the first twenty-seven months.

Family History

There is no history of chronic disease or of any abnormality of the skeletal structures of any member of the family, nor is there any tendency to fragility of bones or fracture. There is one brother in normal health. The mother, during pregnancy, was under observation in our Out-Patient Obstetrical Department and seemed in good health. During her convalescence, following the birth of the patient, the pulse rate averaged 90, but the temperature returned promptly to normal. Twenty-three months later, the mother was found to have definite moderate enlargement of the thyroid gland. The palms were warm and moist. She was nervous and irritable and had lost weight. The pulse rate averaged 100, and the basal metabolic rate was plus 48. The Wassermann and Kahn tests were negative. Gastric analysis of the mother, done several months later when the basal metabolic rate had returned to normal, resulted in a finding of free hydrochloric acid, ranging from 0 to 35, with a total gastric acid, ranging from 20 to 48 in terms of .1 normal hydrochloric acid per 100 cubic centimeters of gastric contents. Blood-serum determinations gave these findings: calcium 9.49 milligrams per 100 cubic centimeters; phosphorus, 3.3 milligrams per 100 cubic centimeters; and phosphatase, 3.9 units. The product of calcium and phosphorus equalled 31.3.

Physical Examination

The patient was somewhat undernourished. The sclera were definitely blue. The teeth were a dirty brown in color with only small areas of white in the outermost edges of the bicuspids. The incisors had no white areas. Both femora, tibiae, and fibulae were curved. The child could stand and walk with assistance. In walking, the right leg dragged slightly, probably the result of previous fractures. The child was mentally bright and physically active.

Results of Investigations of the Patient

The blood Wassermann and Kahn tests were negative. The Mantoux test was also negative.

The blood count showed:

Red blood cells—4,250,000

Hemoglobin—70 per cent.

Color index—.82

White blood cells—5,800

Polymorphonuclear neutrophiles—38 per cent.

Lymphocytes—59 per cent.

Examination of the stools revealed poor digestion of vegetables. They were light in color and pasty, and pH determinations over a two-week period gave an average of 4.4.

Gastric analysis resulted in finding a total acid range of from 1 to 3 with *no free* hydrochloric acid. This was in terms of .1 normal sodium hydroxide per 100 cubic centimeters of gastric contents. Gastric analysis with histamine injection gave a response of free hydrochloric acid from 6 to 35 and of total gastric acid from 9 to 50.

Metabolic studies were done on this patient over a three-day period. The diet was mixed but was considered to be adequate, although somewhat low in calcium content. Equal parts of all ingested food and water were used for chemical determinations of calcium, phosphorus, magnesium, and nitrogen. All faeces and urine were collected and analyzed for the same elements. Results of these studies are given in Table I.

TABLE I

RESULTS OF METABOLIC STUDIES

	Calcium (*Grams*)	Phosphorus (*Grams*)	Nitrogen (*Grams*)	Magnesium (*Grams*)
Food	.6116	.59443	3.9121	.3669
Urine	.00123	.14434	1.7924	.3147
Faeces	.14705	.40118	1.4190	.1817
Retained	.4656 (.0582 per kilogram)	.0489 (.0061 per kilogram)	1.0158	.1537
Comparison of amount in faeces to that in urine	120 : 1	2.8 : 1	.78 : 1	.57 : 1

The daily intake of calcium (.6116 of a gram) was low for a growing child, but the patient was given all the food, including milk, that she would take. The urine output was .2 per cent. of ingested calcium. The normal for infants is less than 5 per cent. The faecal calcium was 24 per cent. of ingested calcium. Calcium *retention* was .4656 of a gram, or .0582 of a gram per kilogram.

The phosphorus *retention* was .0061 of a gram per kilogram. This is somewhat lower than the normal for growing children, which has been determined to be .008 of a gram per kilogram. The *faecal* output is 2.8 times the *urine* output. Adults normally secrete approximately two-thirds of their phosphorus intake in the urine and one-third in the faeces. These findings indicate *deranged* phosphorus metabolism. There was definite nitrogen retention in this period of investigation.

Blood-serum determinations of calcium, phosphorus, and phosphatase were made at different intervals and under different conditions. During two periods in which *no* treatment was given, the serum calcium was normal and the phosphorus was *below* normal, with a calcium-phosphorus product definitely *below* normal. (See Table II.)

When dilute hydrochloric acid and vitamins A, B, C, and D were given, a much better digestion of food resulted, the stools became normal in appearance, and the pH changed from an average of 4.4 to an average of 6.1.

TABLE II

CHANGES IN BLOOD-SERUM VALUES FOLLOWING TREATMENT

Period		Treatment	Blood Calcium	Blood Phosphorus	Product* Ca and P	Serum Phosphatase	Blood pH	Weight Gain (*Pounds*)
No.	Duration							
1		Bed rest following fracture.	10.28	*4.00*	41.12			
2	28 days	5 grains of calcium lactate every 3 hours.	11.09	5.40	59.80	5.6		0.5
3	8 days	1½ fluid drachms of super D daily.	10.48	5.93	61.83			1.0
4	7 weeks	None.	11.60	*3.40*	39.44			0.0
5	25 days	25 c.c. of .1 normal hydrochloric acid per 100 c.c. milk. Vitamins A, B, C, and D.	10.60	4.60	48.76	8.0		0.5
6**	50 days	15 c.c. of .1 normal hydrochloric acid per 100 c.c. milk. Vitamins B and D forced.						0.5
7	30 days	15 c.c. of .1 normal hydrochloric acid per 100 c.c. milk. 3 fluid drachms of cod liver oil daily. High-protein diet.	10.60	5.80	61.48	7.1	7.35+	2.0

*Explanation of products of calcium and phosphorus blood-serum values:
30—Diagnostic of rickets
30 to 40—No ossification
50 to 60—Normal

**During this period measles developed.

Gastric analysis was repeated after a three-day rest period following the courses of treatment previously described. Free hydrochloric acid was then present in the gastric juice and the total gastric acidity was increased. The stools became darker in color and of normal consistency. Food was well digested. The average pH of the stools changed from 4.4 to 6.8. The results of the analyses are recorded in Table III.

Treatment

Following the metabolic studies, treatment consisted of dilute hydrochloric acid which was added to the milk, a *high protein* diet, and cod-liver oil three times daily. At the end of this period the blood pH was 7.35+, the *product* of serum calcium and phosphorus was a *high* normal, serum phosphatase [12] was increased over that of Period 2, and the food was well digested. The patient made her greatest weight gain, and there was roentgenographic evidence of increased bone density.

TABLE III

EFFECTS OF TREATMENT ON GASTRIC ACIDITY, pH OF STOOLS, AND DIGESTION OF FOOD

Period		Treatment	Gastric Acidity (Titration Method)	pH of Gastric Juice (Colorimetric Method) *	pH and Description of Stools	pH of Blood Serum
No.	Duration					
4	7 weeks		Free hydrochloric acid 0 Total acidity 1–3	Total acidity 4.3	Average pH 4.4 Stools: light in color, pasty, food poorly digested. Foul odor.	Not determined.
		After histamine injection	Free hydrochloric acid 6–35 Total acidity 9–50			
5	25 days	25 c.c. of .1 normal hydrochloric acid per 100 c.c. milk. Vitamins A, B, C, and D.	Free hydrochloric acid 0–16 Total acidity 5–34	Total acidity 4.6–3.0	Average pH 6.1 Stools: brown in color, normal in consistency, food well digested. Normal odor.	Not determined.
7	30 days	15 c.c. of .1 normal hydrochloric acid per 100 c.c. milk. 3 fluid drachms of cod-liver oil daily. High-protein diet.	Free hydrochloric acid 0–6 Total acidity 6–11	Total acidity 3.4–2.2	Average pH 6.8 Stools: normal in color, consistency, and odor. Food well digested	7.35+

* Optimum pH for peptic activity and sufficient to produce secretin and to inhibit bacteria is below 3.[5, 10]

A tooth was extracted and examined histologically by one of us (H. E. R.), who reported as follows: "To the unaided eye the enamel is almost transparent and vitreous in appearance. The dentin, likewise, is almost transparent and the pulp, in the form of an opaque mass of comparatively large size and almost cylindrical in form, is readily discernible and extends far into the enamel end of the tooth. The dentin, macroscopically, is of a dirty white color with a slight yellowish tinge. Upon low magnification (×15) the semitransparency is enhanced.

"The tooth cut easily with a saw and although the pieces seemed hard to the touch they were quite soft and were easily ground.

FIG. 1

In the photograph (×4), the pulp cavity (*A*) is evident. This is due to the transparency of the tooth.

"Microscopically the enamel cuticle was well preserved along the sides of the sections and the deeper portion showed the continuations of the enamel rods. The layer of enamel on the occlusal surface is thin and irregular in spots; the enamel rods are straight, regular, and of uniform thickness, exhibiting very few irregularities in outline. The 'brown striae' are absent and the 'lines of Schreger' are almost wanting, being poorly represented near the occlusal surface. There is some brownish discoloration toward the surface of the enamel but this is diffuse in arrangement and not in the form of striae. The interglobular-space region is unusually wide but otherwise exhibits nothing unusual.

"The dentin, under low magnification, exhibits lines of varying widths which course parallel to the surface of the dentin; these seem to indicate varying positions of the dental papilla during the formation of the dentin. Their varying widths seem to indicate varying lengths of time in these *stop* or *rest periods*. The dentinal tubules, however, pass uninterruptedly through these lines and likewise show no alterations at these points. It would seem that these lines represent faults in the intertubular dentin.

"The dentinal tubules are also peculiar for several reasons. They are quite large in diameter, irregular in course, and irregular in distribution; they seem to be arranged in bundles of different sizes and consequently the intertubular dentin is more abundant in some areas than in others. These tubules branch freely especially near the pulp cavity and many of the branches are recurved.

"The structure of the cementum is not so sharp and clear as in the normal tooth; the lamellae are poorly developed, especially superficially. The material seems granular in nature as though the chemical process

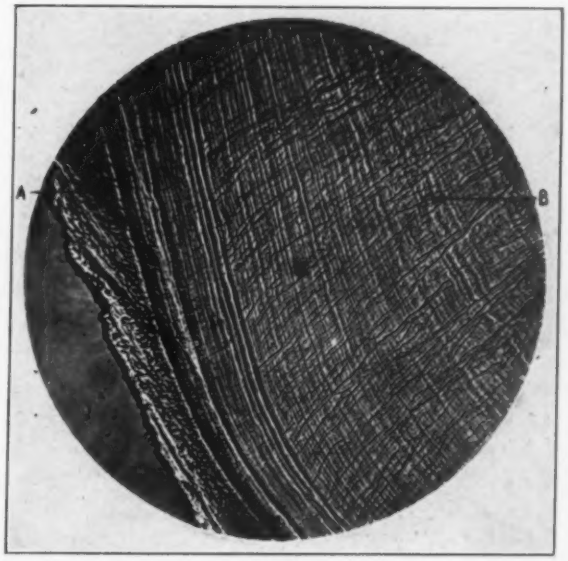

FIG. 2

Photomicrograph (16 mm. obj. × 10 ocular).
A: Enamel showing brownish pigment.
B: Dentin showing the *apparent rest lines.*

by means of which it had been laid down was incomplete. The cementum seemed quite soft and fragmented readily in grinding. It resembled, in structure and appearance, the bone of amphibians and birds."

DISCUSSION

The etiology of osteogenesis imperfecta has never been determined. The mother of this patient, twenty-three months after the birth of the child, was found to have an enlarged thyroid, increased basal metabolic rate, and increased pulse rate. The thyroid enlargement was probably present during pregnancy and we have some evidence that there was an abnormal secretion during this period. Unfortunately, no determinations of the basal metabolic rate were made and no thyroid disturbance was suspected. It is known that toxic thyroid patients have high excretion of calcium and phosphorus and normal blood-serum calcium and phosphorus[1,9]. There is also a tendency to the production of osteoporosis of the bones. It has also been determined that the majority of toxic thyroid patients have low gastric acidity or complete achlorhydria. Approximately one-third of these achlorhydric patients remain so even after histamine injection; in other words, one-third are truly achlorhydric.[2] Tibbetts, McLean, and Aub found that the high calcium and phosphorus excretion is not due to vitamin-D deficiency, and the major factor in producing diminished secretion of hydrochloric acid is the abnormal overactivity of the thyroid gland. The thyroid disturbance of the mother was probably an etiological factor in the deranged metabolism of this child. It is interesting to note Robison's finding that phosphatase, believed now by some to be important in the deposition of bone, is definitely *inhibited* by protoplasmic poisons.

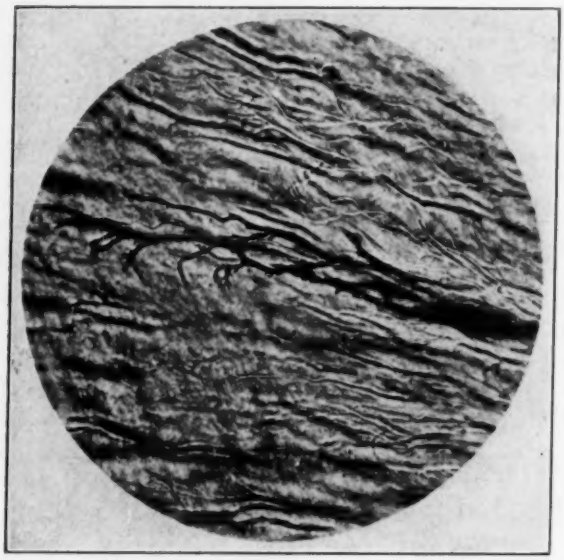

FIG. 3

Photomicrograph (4 mm. obj. × 10 ocular) of the dentin, showing the unusual branchings of some of the dentinal tubules.

This patient was found to have an absence of free hydrochloric acid throughout the digestive cycle when not under treatment; there was poor digestion of vegetables particularly, with tendency to fermentation in the stools. Some stools were pasty and light colored. There was good reten-

tion of calcium with a proportion between the faecal and urine output approaching the normal for adults. This was on a diet low in calcium for growing children [12]. The phosphorus retention was somewhat below the normal range for growing children (.0068 to .008 grams per kilogram) and the proportion of faecal to urine phosphorus output was reversed from the normal found in adults [16]. The blood-serum calcium was normal, serum phosphorus was constantly *low* in the absence of treatment, and the product of calcium and phosphorus was *below normal.* In the absence of treatment, no weight gain or roentgenographic evidence of improved skeletal change resulted.

It is a well-known fact that hydrochloric acid in gastric juice aids peptic digestion. The acid stomach contents stimulates secretions from the duodenum, the liver, and the pancreas. The acid contents of the duodenum should result in the formation of soluble acid calcium and an increase in calcium absorption. Conditions favorable to calcium absorption, in this respect, result in the absorption of phosphorus by increasing its solubility. This reduces the amount excreted in the faeces.

This patient also gave evidence of abnormal metabolism of calcium and phosphorus *after absorption.* In both periods of study when no treatment was given, the serum calcium remained in the normal range, but the serum phosphorus was low and the calcium-phosphorus product below normal. After the administration of vitamin D for eight days, the serum phosphorus was elevated and the product of calcium and phosphorus fell within the range of high normal. This represents the *intermediate* metabolism which vitamin D is known to affect so advantageously.

Peters and Van Slyke state that calcium chemically in the body may be looked upon as playing a *passive* rôle at the mercy of the proteins, phosphorus, pH, and other ions. Phosphorus, on the other hand, exists in a multiplicity of forms independent of calcium, all of which may become *inorganic.* The retention, excretion, and deposition of bone depend on the state, concentration, and supply of inorganic phosphorus. In nutrition the organic compounds of phosphorus are known to excel inorganic compounds even when the latter are given with other foods [12]. Phosphorus in organic compounds exists as nucleoproteins, phosphoproteins, phospholipins (caseinogen and ovalbumin).

In our patient the state of available phosphorus was for the most part *organic.* We have attempted to supply this organic phosphate in large quantities by instituting a high-protein diet and to effect adequate digestion and absorption of the proteins by the administration of hydrochloric acid. Vitamin D was added in the form of plain cod-liver oil and was shown in our particular patient to have a favorable effect upon the concentration of serum phosphorus.

It seems probable, in the light of our present knowledge [3], that phosphatase is an important factor in the deposition of bone or in the synthesis of phosphorus compounds in bone formation [4]. Phosphatase was found to be present in the serum in normal quantity after treatment.

Results of Treatment

Fifteen cubic centimeters of .1 normal hydrochloric acid per each 100 cubic centimeters of milk, three drachms of cod-liver oil daily, and a high-protein diet resulted in a weight gain of two pounds in the thirty-day period. This far exceeded the gain of any other period during observation. Other clinical evidences of improvement following treatment were: (1) whitening of the teeth, (2) definite fading of the blue color of the sclera, and (3) increased physical activity. Laboratory evidences of importance were: (1) elevation of serum phosphorus from 4.6 to 5.8, (2) elevation of the calcium-phosphorus product from a definitely low figure to a definitely high normal, and (3) roentgenographic evidence of increased bone density of the concentric type.

SUMMARY

Investigations of a patient with osteogenesis imperfecta revealed deranged primary and secondary phosphorus metabolism. Absorption and retention of phosphorus were below normal. The blood-serum phosphorus was low and the product of serum calcium and phosphorus values was below normal.

The tooth was defective in development, particularly the dentin and the cementum, both of mesodermal origin. The enamel, of ectodermal origin, was softer than normal and the "brown striae" and the "lines of Schreger" were absent.

The gastric secretion contained no free hydrochloric acid and low total-acid values. This was probably a factor in the poor absorption of phosphorus.

The mother of the patient was found to have hyperthyroidism which was probably an etiological factor in the abnormal bone development and in the abnormal gastric secretion of the child.

The administration of dilute hydrochloric acid and a high-protein diet, to provide phosphorus, and cod-liver oil, for its effect on secondary metabolism of calcium and phosphorus, resulted in better digestion of food, a normal product of serum, calcium, and phosphorus values, and clinical and roentgenographic evidences of improvement.

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OPERATIVE TREATMENT OF TUBERCULOSIS OF THE KNEE JOINT

BY PROF. DR. S. TREGUBOV, KHARKOV, U.S.S.R.

For many years the extensive resection of joints was regarded as the classical treatment of bone tuberculosis. The result was that in many cases the articular extremities were sacrificed, with so much separation of the surfaces that union was difficult. Also, at that time, the technique of fixation was imperfect and the subsequent course was not satisfactory. The open method of treatment of these wounds practically always resulted in secondary infection with its unfortunate sequelae; in most cases the patients were left with extremities poorly adapted for function because of the marked contraction.

Later, after Rollier had published his remarkable results obtained by the conservative method, resections were less and less practised and most surgeons became adherents of the conservative treatment. Rollier's slogan was: "Every case of tuberculosis can be healed if we have only the patience not to operate." His method consisted essentially of heliotherapy at high altitudes, with immobilization in recumbency but without plaster. Heliotherapy, either at high altitudes or at the sea, combined with immobilization by plaster or by traction, then became popular. The favorable early results obtained from this treatment gave an impetus to the conservative method and made it predominant over a long period.

However, continued experience showed that, after a few years of conservative treatment, relapses occurred in a large percentage of cases in which healing had apparently taken place and also that many times, although the pathological condition had healed, the patients were left with limbs unsuited for active use. Surgeons then began to return by degrees to the operative method, combining the conservative and operative procedures. In contrast to their former attempts to remove as much as possible of the bone which appeared affected, it now became their aim to create an ankylosis in the position of election. Moreover, with the recognition of the importance of careful postoperative immobilization, the results became increasingly better, and at present there have accumulated the records of a large number of cases in which this treatment has attained permanent success and from which definite conclusions can be drawn.

Since 1930, when Hibbs had reported 154 cases of operation with good results, a very large number of cases treated with success by the operative method have been recorded by Sorrel, Martens, Calvé, Vaccelli, Henderson, Frédet, Vignard, Maffei, LeFort, Odasso, Mezzari, Rose, Kornev, Friedland, and Frumin. The author's personal experience with the operative method consists of 109 resections performed during the period extending from 1921 to 1934. In comparing the results of the conservative and the operative methods of treatment of tuberculosis of the

knee joint, Martens, of the Göttingen Clinic, gives the following data: of eighty-six cases treated conservatively, good results were obtained in 41 per cent.; of 105 cases treated by operation, good results were obtained in 77 per cent.

Some surgeons continue to recommend conservative treatment, but an increasingly large majority are advocating operation with the object of attaining ankylosis. The important problem today is the estimation of the indications for operation.

At the second Ukrainian Congress of Surgeons, the late Prof. R. R. Vreden reported forty-five cases of fixation by his method, with excellent results. Mention should here be made of the difference between his method and that of Robertson Lavalle. While at first it may seem to be a modification of the Robertson Lavalle method, it has little or nothing in common with that procedure. Robertson Lavalle's technique is based on the supposition that around the infected area there is created a diminution of the blood circulation, a venous stasis, which it is advisable to relieve by drainage. This he accomplishes by making a canal in the bone to the area of infection, and into this canal he inserts a thin lamella of bone to act as a drain. This is by no means a simple procedure, for the focus may be situated outside of the area of stasis, and the object of the operation may not be attained. Independent of the question of the correctness of this method, it must be recognized that it is extremely difficult to determine the location of these foci roentgenographically, and one must be guided entirely by roentgenograms. Often this evidence does not correspond with the clinical picture, and it is, therefore, very difficult to place a drain in or at the exact zone where it is required. This method, as practised by other surgeons, has not given as good results as those obtained by its author.

The nail fixation, a pin of bone, suggested by Vreden, is supposed to have a beneficial effect, on the one hand, by producing a hyperaemia in the region of the nail and, on the other hand, by causing immobilization. It must also be mentioned that this method of fixation has not been readily accepted by the majority of surgeons, and it is now seldom applied. In three cases in which the author was obliged to operate, a fixation had previously been attempted and it was evident that it had contributed to an exacerbation of the process, which diminished only after a complete resection by the other method. One of the cases ended in amputation.

In the same way, the operation proposed by Prof. Kozlovski—an osteotomy above and beneath the joint, the so-called "osteotomia medicata"—has not justified itself by the results.

Before discussing the fundamental operations employed in the treatment of tuberculosis of the knee joint—the classical and the economic* resection—the removal of bone foci and synovectomy should be considered. Waldenström has performed a considerable number of synovectomies in

*This term is commonly used in the U.S.S.R. to denote a resection in which no attempt is made to remove all foci of disease or all of the invaded area.

cases of tuberculosis of the knee joint, always preceded by biopsy for accuracy of diagnosis. After ten years of experience with this operation, he arrived at the conclusion that the results did not warrant its advocacy. Calvé and Alglave also give unfavorable opinions in regard to it.

With reference to the elimination of isolated foci, it cannot be doubted that the early removal is of importance, and it is very evident that para-articular foci may sooner or later invade the joint, resulting in an explosion of the joint symptoms. This operation has not been accepted widely and little favorable comment in regard to it can be found in the literature. The principal consideration in regard to these isolated para-articular foci does not lie in difference of opinion as to when the operation should be done, but, rather, in the fact that they can seldom be seen clearly. Even when roentgenograms are taken in different positions, they frequently do not give the location accurately enough for operative interference. During operations on joints, large and small foci near the epiphyses are often found, which were not visible roentgenographically.

The question of the age at which operation is advisable is an important one and is particularly debatable in regard to children. Volkmann, König, and others have expressed doubt as to whether it is rational to operate on children because of the unfortunate results which sometimes occur. Kirmisson has strongly advised against operating on children, and many of the French orthopaedic surgeons are still opposed to it. Calvé and Galland, in 1925, formulated their opinion in regard to this question as follows: "*Ne jamais réséquer l'enfant, réséquer en principe l'adulte, ne pas tenter la résection chez le vieillard.*" Up to the present time, Calvé does not operate before the age of twenty. Sorrel gives the following formula: "*Chez les enfants, immobilisation; chez les adultes, résection; chez les vieillards, amputation.*" However, in studying his material, it will be seen that of 120 resections, seventy-two were performed on persons under the age of twenty, among whom were eight not yet sixteen years old and twenty-five not yet seventeen years. Therefore, it would seem that he has considerably modified his indications. Girdlestone is apparently of the same opinion, as he advises the surgeon to "avoid operating on very young, very old, and very weak persons". Spitzy prefers to operate only after bone growth has been completed. Krasnobaev is also an adherent of operative treatment of tuberculosis in the knee joint in adults. "It is quite incomprehensible," he says, "how surgeons who have to do with adults can ignore operative treatment as they well know how much strength and time must be wasted by an adult patient in order to remain the winner in the struggle with bone and joint tuberculosis when treated by the conservative method." With regard to children, however, he takes a different view and states: "The experience of the older surgeons who have won good reputations for resections in cases of knee tuberculosis is very great and sufficiently convincing to transfer the indications for this operation to the infantile age, at least from thirteen or fifteen years."

A large number of outstanding orthopaedic surgeons have gradually extended their indications for economic resections in children. The essential requirement is that the epiphyseal cartilages should not be injured.

At the last International Antituberculosis Congress in Warsaw, Maffei stated that he operated on children at the age of five years and that there was no danger of injuring growth, provided that the epiphyseal lines were not damaged. However, in the case of a considerable contraction, especially of a subluxation, it would be extremely difficult to perform an economic resection of the knee of a child without damaging the epiphyseal lines. Therefore, it is of the utmost importance to prevent the development of a contraction.

Among the Russian authors, Kornev has collected a large amount of data in regard to knee resections during infancy. He operated on children of less than ten years of age. In 1930 he reported that 23 per cent. of his resections were in children less than ten years old and that 41 per cent. were in children from ten to fifteen years of age. In other words, 64 per cent. of the resections of the knee were in children less than fifteen years of age. From periods of observation ranging from one to seven years, he has found that the average shortening in these cases was five centimeters. He, therefore, concludes that this age should not be considered a contraindication for performing an economic resection.

If we bear in mind how often the paths of infection pierce the epiphyseal lines, destroying them to a great extent, we may well conclude that the adherents of economic resection on children have good reason for operating at an early age, provided that they do not injure the epiphyseal cartilages. Moreover, one may well question whether it is rational to wait eight, eleven, or even fifteen years to perform the operation, when, during these years, there may be inflicted on the epiphyseal lines much greater injury by the destructive process than might be caused by an operative interference cautiously carried out. Finally, one should consider whether the shortening produced by conservative treatment is much less than that caused by an economic resection.

The other important question to be determined is the stage of the disease at which it is preferable to operate. The majority of surgeons are of the opinion that the period of abatement of the process is the most suitable. Sorrel's answer to the question is as follows: "*Il ne faut pas opérer les tuberculeux jeunes; il faut les laisser vieiller.*" Of the same opinion is Calvé, who states: "*Mes résections sont toujours tardives.*" In general, he believes that operation should not be performed until two years after the onset of the disease. Kornev and Lourie also advise against operative treatment during the initial stages of the process.

However, a number of experienced orthopaedic surgeons, principally Americans, advocate operative interference as early as possible. Hibbs, Allison, Osgood, and Henderson have advised such interference as soon as the diagnosis has been determined. Yessipov thinks an operative interference is necessary in children "in cases of open fistulae with secondary

infection in the great joints; in the presence of sequestra; when the conservative treatment has been prolonged and shows no progress; and when the strength of the child is evidently exhausted". He further states that "operative interference in cases of fistulae in the joints consists of a radical resection of the joint, taking care not to injure the epiphyseal cartilage. Therefore, if possible, the operation should be performed according to the economic type." Kornev also does not consider that the presence of fistulae is a contra-indication for resection of the knee. Maffei operates not only during the period of abatement, but also during the stage of development of the disease. However, he does not advocate operating during the acute period, preferring to delay operative interference until at least six months after onset of the disease. He lists the following conditions as contra-indications: an acute period of the disease; simultaneous affection of the lungs, the kidneys, and the intestines; fistulae with secondary infection; cases in which it is clear that ankylosis is developing; doubtful cases in which after some months of quiescence there seems to be full recovery; and cases in which the temperature is above 38 degrees centigrade.

In this discussion of the technique of operative interference in tuberculosis of the knee joint, it is the author's purpose to consider the classical resection and the so-called economic resection or arthrodesis. It seems unnecessary to consider the introduction of drugs into the joint cavity, removal of para-articular bone foci, or excision of the synovial membrane. While the majority of surgeons think it necessary to remove carefully all affected soft tissues and joint ends, together with the patella, just as if they were a malignant neoplasm, others believe this to be entirely superfluous. Although a supporter of the simple classical resection, Sorrel endeavors to remove all soft tissues, together with the patella. Basset, Frédet, Waldenström, and Calvé remove the capsule and the patella. Kornev employs the same technique except that he removes the portion of the patella next to the affected joint, leaving the upper part in place. Mezzari opposes resection and prefers extra-articular arthrodesis according to the method of Delahaye-Zanoli. Putti also favors extra-articular arthrodesis. Waldenström removes the capsule and the patella like a neoplasm and resects the tissues high up on the femur behind the condyles. The extremity is then encased in plaster and placed in a slightly raised position. At the end of three months the patient is allowed to bear a little weight on the foot. After from eight to ten months, the plaster bandage is replaced by a leather case.

Although formerly it was considered essential to remove the foci of infection, together with the surrounding bone, at present the procedure is confined to a more or less elaborate scraping out and packing of the cavity. Kornev fills the cavity with a soft iodoform-vaselin paste; Friedland uses sterilized vaselin or autoplastic fat; Frumin swabs with liquid carbolic acid which is then neutralized by absolute alcohol; and others pack the cavity with bone chips.

TABLE I

AGE INCIDENCE

Period (Years)	No. of Cases
8 to 10	3
10 to 15	7
15 to 20	56
20 to 25	37
25 to 45	41
45 to 53	3
Total	147

The tourniquet may or may not be used, according to the preference of the operator. The section of the bone is done in several different ways. Calvé uses a double parallel saw which permits the proper correlation of the bone surfaces. Kornev saws the bone in the form of an arch, which makes it possible to resect a smaller piece of bone, thereby producing less shortening. Sorrel generally resects less than five centimeters on the tibial side and three centimeters on the femoral side. Only a few surgeons (notably Leriche and Henderson) resort to fixation with the aid of clamps or metal wire, most surgeons now believe this to be not only unnecessary but even inadvisable, because of the protracted osteomyelitis which occasionally follows. A position of slight flexion is desirable; great care should be taken to avoid the position of genu recurvatum. It is very important that the knee should be held in the desired position and that the cut surfaces should not be displaced. Such displacement can be avoided, to a certain extent, by carefully sewing with strong catgut the rims of the periosteum which have been turned back. A plaster bandage, with a thin layer of cotton-wool, is then applied to the limb, including the foot and the pelvis.

There is no unanimity in regard to the question of whether or not a drain should be left after the operation. The majority of operators do not leave either a drain or a tampon.

The period of immobilization varies with the different operators, but the tendency is toward long-continued fixation. Sorrel removes the belt at the end of two months and changes the other part of the bandage a month later. If full consolidation has not taken place at this time, he recommends the wearing of a plaster splint for an additional two months, followed by a celluloid apparatus. This latter piece of apparatus may usually be discarded in a month. Calvé immobilizes the leg for three months and then, if sufficient ankylosis has developed, he allows weight-bearing without any apparatus. However, if there is evidence of any mobility, a plaster bandage is reapplied and the patient is permitted to bear weight on the foot.

TABLE II

DURATION OF DISEASE BEFORE OPERATION

Years	Cases
2	3
3	8
4	10
5	12
6	10
7	12
8	11
9	15
10	29
11 to 20	31
20 to 30	6
Total	147

Of the total number of patients with bone tuberculosis who have been treated in the Out-Patient Department of the Orthopaedic Clinic of the Kharkov Medical Institute during the period from 1921 to 1936, 609 had tuberculosis of the knee joint; of these, 147 were treated surgically. At first, operations were performed only on adults and in cases where the disease had abated. Later, we very cautiously extended the indications, both in regard to age and the stage of the process. We did not risk operation in the initial stages, but we began to operate in the developmental periods. Table I shows that the number of children under fifteen years of age was not large, but that the greatest number of patients operated on were between the ages of fifteen and twenty years. There were sixty males and eighty-seven females.

Operations were never performed until at least two years after onset of the disease. Table II shows that in nearly 45 per cent. of the cases the disease had been in progress ten years or more before operation. The pathological indications were as follows: contraction, 90 per cent. of the cases; subluxation, 20 per cent.; full luxation, 1 per cent.; fibrous ankylosis, 70 per cent.; osseous ankylosis with pathological signs, 30 per cent.; and a local rise in temperature, 50 per cent. In fifty-four cases, the resected tissues were examined microscopically and the diagnosis of tuberculosis was not confirmed in only six cases.

In principle, the technique of resection followed at our Clinic differs little from that used by other surgeons. While earlier we carefully resected the capsule, we now confine ourselves to removing a wedge of bone which includes the affected joint. The wedge should be of such shape and size that it may be set in the position of slight flexion. The size should be calculated as accurately as possible in order to obviate later correction by sawing off new pieces of bone. If areas of pus or cavities filled with granu-

lated masses are found, they are resected. The resection may be slightly modified according to circumstances, but, in principle, it remains essentially an economic one.

It is easily understood that in cases of considerable and obstinate contraction with subluxation a large piece of bone must be resected. However, in cases in which the contraction can be corrected by a series of preliminary bandages, such correction is advisable in order to limit the amount of bone to be resected. Moreover, section of the flexors and the tensor fasciae latae renders it easier to place the leg in the required position. Severe and obstinate contractions in children present grave difficulties, because of the danger of injuring the epiphyseal cartilages. However simple the operation of economic resection may be in the case of a small contraction, it always becomes difficult when the contraction is marked; in such a case the saving effected by the making of an arch does not help much.

We have never used any pins for fixation, but have utilized with success a method proposed by Sorrel,—namely, the drawing back of the periosteum along the line of incision and sewing it together again after the operation. This facilitates the union in the correct position of the cut surfaces. Sutures of strong catgut provide sufficient fixation.

With a chisel, a piece of bone, corresponding in size and form to the cavity, is cut from the sound part of the resected bone or from the patella and, after the cavity has been thoroughly curetted, this piece of bone is pressed into it. If the cavity is large, several chips of bone are necessary to fill it. In no case has this graft failed to unite, nor have complications followed. In the majority of cases the cavities are either invisible or seen dimly in the roentgenogram; usually they are filled with purulent or granulated masses. During the last few years, it has been our practice to leave in a tampon for twenty-four hours to prevent the development of hematomata.

The operating table has a support for the pelvis-holder; therefore, it is not necessary to transfer the patient from one table to another. A broad splint in the form of a trough serves for preliminary fixation. The plaster bandage which encloses the pelvis and the foot is put on with a small quantity of cotton-wool in such a manner that the plaster may be modelled carefully.

At the end of approximately six weeks, the patient is permitted to walk on crutches and to bear weight slightly on the affected leg. Three months after the operation, the plaster bandage is shortened, or replaced by a new bandage without a belt. This second bandage is worn for an additional three months. During this period the patient may bear weight freely on the leg. At the end of this time, a removable bandage, made of plaster and gelatin or of gelatin and formalin, is applied. The length of time during which this apparatus is worn is governed by the firmness of the ankylosis and by the evidence furnished by control roentgenograms.

In a large number of cases, for several days after the operation, there

was a rise in temperature, but this was only transient and the temperature became normal in the course of two or three days. In the rare cases in which operation was performed at a relatively early stage of the disease (two or three years after onset) this rise in temperature lasted for from one and one-half to two months.

In a number of cases an ideal adjustment of the resected surfaces was not obtained, but this did not noticeably affect the stability of the extremity. In some cases it was necessary to correct the position after operation. This was difficult to do and was accomplished by changing the position of the bandages. The length of time required for firm ankylosis varies and is governed by a number of factors,—accuracy in the adjustment of the cut surfaces, the age of the patient, maintenance of fixation, the stage of the process, etc.

Of the 147 patients operated upon (five amputations and 142 resections), we have written reports on forty-eight, and fifty-five have appeared for examination. Two patients had died two years after operation; in one case death was due to accidental infection and in the other to tuberculous meningitis. In both cases, however, complete healing of the gonitis had occurred. In the other forty-six cases, good results had been obtained and the patients had returned to normal life. The fifty-five patients who appeared for examination were all in excellent condition.

An excellent result was obtained in the case of a female patient, aged fifty-three years, in which the cut surfaces were like honeycombs filled with purulent matter. Fibrous ankylosis occurred in only two cases, but both of these patients reported that they felt well.

Among the patients operated on at other institutions was a female, forty-nine years old, whose knee had been resected at the age of nineteen. The position of the joint is excellent and there is shortening of only four centimeters. There is full function and her only complaint is of general fatigue in the leg after walking for a long time.

In one case, three years after a "nailing" operation had been performed, union had not taken place and fistulae had formed with persisting pain. Roentgenographic examination showed atrophy of the joint surfaces and in the background a long pin jutted out. This patient decided upon amputation.

At resection of the knee joint of another patient, an ivory pin, surrounded by granulations, was found. The canal was carefully cleaned and the resection was performed. The postoperative period was uneventful with the exception of a somewhat protracted period of fluctuations in temperature. At the end of a year ankylosis had not taken place and the knee was slightly painful and could not be used normally. Amputation was, therefore, decided upon.

The author resected the knees of two other patients who had previously undergone the "nailing" operation and ankylosis had not taken place. Following resection, firm ankylosis developed and both patients have returned to work.

In the ten cases in which resections were performed on the knees of

children under fifteen years of age, there was grave danger of injuring the epiphyseal cartilages, due to the acute angle of the contractions which necessitated the removal of large pieces of bone. However, control roentgenograms taken immediately after operation showed that the epiphyseal cartilages had not been damaged. Further study disclosed the disappearance of atrophy. In regard to the sequelae of our resections on children, we must mention a certain tendency toward the development of an angle of flexion at the area of ankylosis. This is to be explained by disproportionate growth of the epiphyses, a phenomenon that is often met with in cases of tuberculosis of the knee joint. Taking this tendency into consideration, at present after an operation on a child, we always fix the extremity in a straight position, and not at a slight angle as in an adult.

FIG. 1

In the case of a female, operated on in 1905, the roentgenogram (Fig. 1) showed the structure in the region of the lower part of the femur and the upper part of the tibia to be homogeneous and the cortex well defined.

The stability of the leg and the sensations of the patient are just the same whether or not the patella has been removed. There were only two cases in which shortening amounted to seven centimeters; in the other cases it averaged between three and four and five-tenths centimeters. However, the shortening of seven centimeters did not inconvenience the patients, although their occupations involve physical labor.

CONCLUSIONS

1. In treating tuberculosis of the knee joint, the best results are obtained by operative intervention.

2. At present we are not concerned with the question of whether or not an operation should be performed, but with more accurate indications for the operation.

3. Adolescence and maturity are the most suitable ages for operation. Excellent results have also been obtained in old age. Evidence has also been accumulating which indicates that economic resection may be successfully performed on patients between the ages of ten and fourteen, if care is taken not to injure the epiphyseal cartilages.

4. The best time to perform an operation for ankylosis is the period of abatement of the process. The initial stages of tuberculosis in the knee joint are not suitable for operation.

5. The success of operative interference does not depend upon the removal of all affected tissues. The operation should be a simple one, aiming chiefly at the formation of ankylosis. The bone foci should be thoroughly curetted and filled with bone chips.

6. No clamps, braces, or wires should be employed, but it is important to fix the knee in a position of slight flexion.

7. Neither the operation of Robertson Lavalle, nor "nailing", nor "osteotomia medicata" is to be recommended in cases of tuberculosis of the knee joint.

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NOTE: The subject of low-back derangement is occupying the attention and enlisting the interest of a very large number of orthopaedic surgeons, and the difficulty of differentiation of the various conditions causing low-back pain and resulting from low-back strain is fully recognized. At the Meeting of the American Academy of Orthopaedic Surgeons, held at Cleveland in January, a symposium on this subject was conducted. The papers presented at that symposium are published in this issue as a group, with the concluding remarks of the Chairman, Dr. Joel E. Goldthwait, whose name has been so intimately and for so long a time associated with this particular problem.—*Editor.*

LOW-BACK PAIN

THE ANATOMICAL STRUCTURE OF THE LUMBAR REGION, INCLUDING VARIATIONS *

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To understand properly the anatomical structure of the lower back, and to appreciate its susceptibility to aches of obscure etiology, consideration must begin, not with the cadaver on the dissecting table, but with the ancestral spinal column from which that of man has evolved, and with the manner in which the lower extremity develops and becomes attached to the vertebral column.

In early foetal life the ilia, developing in the hind-limb buds, approach the vertebral column and become attached to the transverse processes of one or more vertebrae. These, assuming such special responsibility, enlarge, fuse, and become the sacrum. The points of attachment become the sacro-iliac joints.

Within each animal species there is variation as to the particular vertebrae with which the ilia articulate, and this variation is frequently bilaterally asymmetrical. In addition to such individual variability, there is either progressive or retrogressive fixation of the pelvic complex to the vertebral column, appearing in different zoological species derived from common ancestral types.

In the evolution of man, the pelvis has progressed toward the head by incorporation in the sacrum of successive last lumbar vertebrae, the next preceding segment thereupon assuming the characteristics of the last lumbar segment. At present, the human spinal column has a modal number of twenty-four presacral segments, varying to twenty-five in 3.5 per cent., and to twenty-three in about 1 per cent.

Of more interest in the present clinical discussion than simple addition to, or subtraction from, the length of the presacral column are the much more common partial sacralizations and lumbarizations. Whether the involved segment be the twenty-third, twenty-fourth, or twenty-fifth is of little importance. Such anomalies are manifested by enlarged trans-

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 14, 1937.

verse processes on one or on both sides of the last lumbar segment, which may impinge on, articulate, or fuse with the lateral mass of the sacrum, or articulate with the ilium. Another evidence of partial sacralization is variation in conformation of the articular processes, and in their planes of incidence, between the sagittal lumbar and the transverse sacral types.

Still a third manifestation of partial sacralization of a last lumbar segment, and one that is often wrongly interpreted as a pathological lesion, is narrowing of the lumbosacral disc. In anomalous sacralization, the vertical diameter of this disc may vary between the diameter of the usual thick lumbosacral type and that of the thin sacral disc. A thin disc is in itself no proof whatever of a destructive or pathological lesion. Particularly, if such a disc is associated with enlarged transverse processes or other evidence of anomalous sacralization, as are most of those shown in clinical discussions, such pathological interpretation must be received with considerable reservation.

Partial sacralizations, in which the transverse processes of the last lumbar segment made actual contact with the sacrum or the ilium, were found in 7 per cent. of 748 vertebral columns examined. In this study it was impossible to determine the incidence of anomalous processes not making actual contact, because a normal from which variation could be measured could not be established. Such enlargement, however, was unmistakable in more than 15 per cent. of the vertebral columns.

A second type of anomaly of interest in low-back pain is defective development of a vertebral arch, particularly the arch of the last lumbar vertebra, with consequent break in bone continuity of the arch. This defect may appear centrally, as in spina bifida, or laterally, freeing the superior articular processes and the vertebral body, which supports the superincumbent body weight, from the inferior articular processes, which anchor this weight to the sacrum and to the pelvis. When such a defect is bilateral, stability of the torso on the pelvis depends entirely upon fibrous attachments between the fragments of the arch.

This anomaly has been found at this site in about 6 per cent. of dissecting-room subjects. It has been interpreted as fracture of the arch, but this explanation does not seem probable for the following reasons: (1) in about 25 per cent. of the cases the anomaly appears unilaterally; (2) the laminae affected are often defectively developed; and (3) in no instance so far reported has there been evidence of attempted bone repair, even in the unilateral type.

The spinal column of the newly born human, like that of the quadruped, presents a single curve,—a backward convexity. When the infant extends his neck, a cervical curve develops, and when he extends his hips, a lumbar curve is present. As he sits upright, the cervical curve becomes established, and as he walks, the lumbar curve becomes fixed, although the adult type of curve is not fully impressed for several years.

The 90-degree adjustment of the human back to the upright posture is accomplished partly through increased extension of the hip joints, but

more through hyperextension of the lumbosacral and lower lumbar articulations. Extension of the hips stretches the anterior hip ligaments and muscles. Lumbosacral hyperextension stretches the anterior vertebral ligaments and muscles, compresses the lumbosacral intervertebral disc posteriorly, allows contracture of the posterior lumbar muscles and ligaments, and forces the inferior articular processes of the last lumbar vertebra downward over the superior processes of the sacrum. The less hip extension is developed, the greater must be lumbar hyperextension, or lordosis.

The sacrum is not wedged between the ilia like the keystone of an arch, but is slung between them on strong ligamentous and minor muscle attachments. Anteriorly, the short transverse sacro-iliac ligaments bind the bones together. Posteriorly, the sacrum hangs on tough fibrous bands extending between the rough iliac tuberosities and the back of the sacrum. Distally, the sacrosciatic ligaments help to stabilize the articulation.

In quadruped posture, the sacrum, slung between the hind-limb supports, carries only the weight of the distal part of the torso. In erect posture, it must also support the thorax, the head, and the upper extremities, all of which are half balanced on its proximal end. The mechanical strains resulting from this arrangement are terrific. Increasing lordosis not only increases the strain but, by approximating origins and insertions of the lumbar muscles, cripples the protective mechanism.

The clinical importance of lumbosacral anomalies and of postural variations is in direct proportion to the extent to which they weaken the part mechanically. The presence or absence of a lumbar segment is of little interest. Enlarged transverse processes, impinging on or articulating with the sacrum or the ilium, or variations in the planes of the articular processes are of importance only as sites perhaps abnormally susceptible to injury. To what extent such anomalies actually predispose to strains and sprains is problematic. Data recently furnished by Badgley and Hodges indicate that it is very little. The former, in a study of several hundred patients complaining of backache, found these anomalies in 26 per cent.; the latter, in the same number of patients without back pain, found them in 27 per cent. They were present in the same proportion of our dissecting-room subjects, some, but not all, of whom probably had low-back pain during their lives. The presence of such anomalies in the vertebral column, therefore, does not solve the problem of backache.

The bilaterally defective neural arch does weaken the anchorage of the torso to the pelvis at the point where the strain of the upright posture is centered. Such arches are definitely separated by injuries. Before separation it is difficult to distinguish them and they are, no doubt, frequently overlooked. Only a small minority of these arches found in the dissecting room have been separated or show spondylolisthesis.

With skeletal anomalies there are, of course, associated variations of the soft tissues, but nerves, muscles, and blood vessels develop with the anomalous bones and must, therefore, be adjusted to them. The butterfly

transverse process does not suddenly develop, pushing nerve trunks aside. The possibility that such processes cause enough tension on the nerve trunks to produce neuralgia or neuritis has been discussed in the medical literature. Analogy has been drawn between such a cause of sciatica and the cervical-rib syndrome. Sciatic pains have been relieved after removal of enlarged transverse processes, and brachial pains have been alleviated following release of tension over a cervical rib. On the other hand, both anomalies exist for years without symptoms, until the relation of nerve to bone is altered by changing posture. The pain in both conditions is often relieved by correction of the faulty posture. However, the treatment of this problem is a clinical consideration.

SUMMARY

The various tissues of which the lower back is composed are particularly liable to aches and pains because of the mechanical strains centered upon them by assumption of the upright posture and by the incidence at this site of anomalies and defects of development.

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THE OPERATIVE TREATMENT FOR LOW-BACK PAIN *

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The patients whose case histories were studied for this report were treated by several different surgeons of the University of Chicago Clinics. Only the author, however, can be held accountable for any theories expressed or conclusions reached in the course of this presentation.

So long as surgeons disagree in regard to the pathogenesis of chronic low-back pain, there cannot be any uniformity of opinion concerning treatment. The same indications for operative treatment are rarely stated by any two men who have written upon this subject. Each surgeon has his own explanation of the primary causes of low-back pain, his own program of conservative treatment, and, if operation is decided upon, his own pet variation in technique for carrying out his favorite operative procedure. Those surgeons who advise operation for almost every patient with a chronic lame back are considered to be extremely radical by those who do not operate at all. This question once more brings up the problem of whether or not the sins of omission, or failure to operate in low-back conditions in which there are definite indications for so doing, are greater than the sins of commission of those surgeons who are less critical in analyzing their patients to determine whether or not there are sufficient indications for surgery. There must be a middle road which it would be profitable for us to travel.

Many operations, involving separate principles and based upon individual hypotheses, have been devised and advised for the relief of low-back pain. The following are a few of those which have been described:

1. *Lumbosacral fusion*, by the method of Hibbs or Albee or by some modification of their techniques.
2. *Sacro-iliac fusion*, as described by Smith-Petersen, Gaenslen, and Campbell, or a modification of these methods.
3. *Trisacral fusion*, by the method of Chandler or by a combination of one of the techniques for fusing the lumbosacral or sacro-iliac joints.
4. *Facetectomy*, as described by Putti, Ghormley, Williams, Yglesias, and Mitchell.
5. *Section of the iliotibial band*, advised and described by Ober.
6. *Section of the piriformis muscle*, as described by Freiberg.
7. *Subperiosteal stripping of the gluteus maximus muscle*, suggested by Heyman.

The author's opinion as an individual can carry little weight, but the

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majority of those members of the American Academy of Orthopaedic Surgeons and of our colleagues in other countries who have written upon this subject have favored some type of arthrodesing operation, when surgery would seem to be definitely indicated.

An analysis has been made of all of the patients whose primary complaint on entrance to the University of Chicago Clinics was that of low-back pain. In this analysis, patients who were admitted primarily because of another complaint, but who subsequently received treatment because of backache, have not been included.

Of 139,000 patients registered at the University of Chicago Clinics between 1927 and 1936, 2242 came because of low-back pain. This is an incidence of 1.6 per cent., a figure which is far lower than the author had imagined, since backache is one of the commoner complaints of adult patients who enter our Orthopaedic Out-Patient Department. Seventy-six of the 2242 patients were subjected to operative treatment. This incidence of 3.4 per cent. indicates the conservative attitude which we have tried to observe toward the question of surgery for the relief of low-back pain. Of the seventy-six patients who were operated upon, there was definite pathology in forty-seven. This pathology consisted of spondylolisthesis, spinal-cord tumors, bone tumors,

TABLE I

ANALYSIS OF SEVENTY-SIX CASES TREATED BY OPERATION

DEFINITE PATHOLOGY—47 CASES

Pathology	Treatment	No. of Cases
Spondylolisthesis	Fusion of fourth and fifth lumbar vertebrae to sacrum	14
Lumbosacral or sacro-iliac tuberculosis	Fusion	8
Chronic osteomyelitis of the sacro-iliac joint	Fusion	6
Primary malignant neoplasms	Biopsy and x-ray therapy	4
Lesions of spinal cord or of the meninges	Laminectomy and partial or complete excision of tumor	15

CHRONIC STRAIN OR ARTHRITIS—29 CASES *

Operation	Joints Fused	No. of Cases
Arthrodesis	Sacro-iliac	7
Arthrodesis	Lumbosacral	10
Arthrodesis	Lumbosacral and one sacro-iliac	6
Arthrodesis	Sacro-iliac and symphysis pubis	1
Trisacral fusion		5

* These patients ranged in age between 13 and 54 years; the average age was 30 years.

tuberculosis, and chronic sclerosing osteomyelitis. In addition to these patients, there were twenty-nine who were operated upon because of the diagnosis of chronic strain, subluxation, or arthritis. The twenty-nine patients, who had only low-back pain without any roentgenographically demonstrable pathology and upon whom arthrodesing operations were performed, represent an incidence of 1.3 per cent. The fourteen patients upon whom arthrodesing operations were performed because of spondylolisthesis were improved or completely relieved. Including the twenty-nine cases in which there were no roentgenographic abnormalities other than common lumbosacral developmental anomalies, there were in our series fifty-seven patients who were subjected to arthrodesing operations. Two patients who were operated upon because of tuberculosis died subsequently of amyloid disease.

Of the twenty-nine patients upon whom were performed arthrodesing operations for chronic strain or arthritis, with or without congenital anomalies of the lumbosacral region, twenty-two were improved or made a complete recovery. There were seven failures, probably attributable to a poor selection of the cases. Four were patients with chronic arthritis which, at the time of operation, was thought to be localized to the low-back region, but which proved to be a progressive process and spread to other levels in the spine and in some instances to other joints as well. One patient was a compensation case and did not obtain any relief from the operation until after a satisfactory financial settlement had been made. This and similar experiences led us to adopt a policy of refusing to do arthrodesing operations on the spines of patients who were compensation cases until after settlement had been made. One patient was definitely a psychiatric case, although this was not recognized in time to prevent what proved to be an unsatisfactory operative procedure. In this instance, a trisacral fusion was carried out, but the patient continued to complain that her back was "twisted" and her hips were "lopsided" and, when she was discharged, she went to a hospital in the East where the trisacral fusion was again performed with the same degree of failure. There was one death on the third day after a trisacral fusion, as a result of circulatory failure.

Most low-back lesions can be localized to one or to both sacro-iliac joints or to the lumbosacral region by careful physical examination. The operation of trisacral fusion is in the nature of a shot-gun procedure and should rarely be advised.

Table II is included to emphasize the fact that not all patients with intractable low-back pain, which is not relieved by a conservative program, should be subjected to arthrodesing operations or to other orthopaedic surgical procedures. In all of the fifteen cases included in this table the patients complained of low-back pain, or of sciatica, or of a combination of the two. Most of these cases had been previously diagnosed as chronic low-back strain or arthritis, and, in several instances, the patients had been treated by plaster-cast immobilization, braces, or physical-therapy

TABLE II

LOW-BACK PAIN CAUSED BY NEUROLOGICAL LESIONS

Case	Age (Years)	Sex	Symptoms	Diagnosis *
1. E. C.	54	Female	Low-back pain	Fibrochondroma of cauda equina
2. Y. C.	47	Male	Low-back pain, sciatica, and weakness of legs	Fibrochondroma of cauda equina
3. H. S.	47	Male	Low-back pain and sciatica	Intraspinal chondroma of intervertebral disc
4. J. W.	54	Male	Pain in lumbar region and in right leg	Tumor of cauda equina
5. D. G.	30	Male	Pain in low back and in both legs	Giant-cell tumor of twelfth thoracic and first and second lumbar vertebrae
6. B. L.	58	Male	Low-back pain and difficulty in walking	Hemangioma of epidural space
7. E. T.	45	Female	Pain in thigh and later in low back	Tumor of cord at eighth, ninth, and tenth thoracic vertebrae
8. L. S.	49	Male	Pain in back and in legs	Capillary hemangioma of cauda equina
9. P. K.	54	Male	Low-back pain and bilateral sciatica	Tumor of filum terminale
10. K. S.		Female	Severe low-back and abdominal pain	Neurofibroma of eleventh thoracic segment
11. R. B.	2½	Male	Pain in leg, limp, and weakness	Giant-cell tumor of conus medullaris and of cauda equina
12. D. W.	3	Male	Pain in both legs	Intramedullary dermoid cyst
13. F. K.	47	Female	Pain in back and in legs of 6 years' duration	Cystic neurofibroma of tenth to twelfth thoracic vertebrae
14. K. B.	23	Female	Pain in sacro-iliac region and down both legs	Extradural fibroma of fifth lumbar vertebra
15. B. K.	22	Female	Pain in groin and in low back, numbness in leg	Extradural cyst at lumbosacral level

*Diagnosis made or confirmed by operation.

exercises over a period of months or of years. Fourteen of the fifteen patients were improved or relieved of their symptoms following operation by one of the neurosurgeons of the University of Chicago Clinics.

Case 15 is deserving of some further comment.

This patient, B. K., female, aged twenty-two years, entered with the complaint of low-back pain of several years' duration. She also complained of pain in the right lower quadrant of the abdomen, for which an appendectomy had been performed without relief, pain in the hip, and pain in the urinary bladder when she voided. There was a history of intermittent attacks of nausea, vomiting, and headaches. The first impression was that she was suffering from a rather marked psychoneurosis. A roentgenographic examination, however, showed congenital anomalies of the lumbosacral region and definite scoliosis with lateral wedging of the lower lumbar vertebrae. (See Figure 1.) Cystoscopic studies revealed a cord bladder. An operation was performed with the intention of arthrodesing the lower lumbar spine with the sacrum. The posterior bony wall of the

sacral canal was found to be almost paper-thin, and, when it was opened, a large, bluish, fluid-filled sac bulged through the defect. When the sacral canal was further explored, it was found to be markedly enlarged, and an extradural cyst, which extended from the upper level of the fourth lumbar vertebra to the lower level of the third sacral vertebra, was removed. Little benefit was derived from the operation. The neurological findings have persisted, and the patient continues to complain of the pain previously described, although the spine was fused following excision of the cyst.

FIG. 1

Case 15. B. K. This patient had multiple developmental anomalies of the lower lumbar spine, partial saddle anaesthesia, and pain in the low back and urinary bladder. A large extradural cyst, extending from the third lumbar vertebra to the third sacral vertebra, was removed at operation, and the fourth and fifth lumbar vertebrae were fused to the sacrum.

Four patients who presented themselves because of low-back pain had been under treatment because of a diagnosis of chronic arthritis or of strain. In each of these cases, further examination revealed a neoplastic lesion in the region of the sacro-iliac joint. Three of the lesions were undifferentiated round-cell sarcomata and one proved to be a chondrosarcoma. Final diagnosis was made in each case by biopsy and partial excision. The following case is typical of the patients in this group.

J. A., a female, aged twenty-five years, came to the University of Chicago Clinics because of pain in the back and right-sided sciatic neuritis of two years' duration. Prior to being seen by the orthopaedic consultant, a diagnosis of arthritis was made and the patient was subjected to tonsillectomy and extraction of two teeth. Orthopaedic examination revealed a firm palpable tumor over the left sacro-iliac region, and a roentgenogram showed an area of bone destruction on the left side of the sacrum, extending across the joint and involving a small area in the left ilium. (See Figure 2.) Biopsy showed gross tumor tissue in the sacrum, in the sacro-iliac joint, and in the ilium. The microscopic diagnosis was undifferentiated round-cell sarcoma. This patient was treated intensively with x-ray, and, although left sciatic-nerve paralysis developed, she was alive and showed no evidence of metastasis two years after initiation of therapy.

The following report illustrates still another variation.

I. W., a female, aged thirty-seven years, was admitted to the University of Chicago Clinics because of pain in the back at the lumbosacral level. There was no sciatic

FIG. 2

J. A. This patient was treated for supposed arthritis. A tonsillectomy was done and two teeth were extracted. The roentgenogram shows a lytic lesion in the left wing of the sacrum with extension into the adjacent portion of the ilium. Microscopic diagnosis of tissue from this area was "undifferentiated round-cell sarcoma".

FIG. 3

I. W. This was a case of chronic lumboscaral strain. The disability markedly increased after lipiodol injection. Complete recovery followed laminectomy, partial excision of lipiodol material, and lumbosacral arthrodesis.

neuritis. This patient had been examined in several other clinics and a diagnosis of chronic low-back strain had been made. Two years prior to her admission to the University of Chicago Clinics, five cubic centimeters of lipiodol had been injected into the spinal canal. This revealed no block and the lipiodol was not removed. In spite of the fact that the patient had been given spine braces and physical therapy, she stated that the back pain had become very much more marked following this injection. She described a sensation of weight or of pressure at the level of the first or second sacral vertebra. Our roentgenograms showed a large amount of lipiodol streaked throughout the lumbar portion of the spinal canal and a mass of this material, one and five-tenths centimeters in diameter, at the lumbosacral joint, with additional amounts as low as the second sacral vertebra. A lumbosacral arthrodesis was advised and during this operation the sacral canal was opened and a mass of encysted lipiodol material was removed. The roentgenogram (Fig. 3) shows the condition following operation. Lumbosacral fusion has been successful. There is a space, one centimeter in diameter, from which most of the lipiodol has been removed, but considerable amounts of this material are still present. The patient is clinically free from symptoms.

Based on these experiences, the author would be inclined to list the following contra-indications to low-back fusion operations:

1. Infectious or multiple arthritis.
2. Compensation cases before financial settlement.
3. Elderly or poor-risk patients.
4. Female patients before puberty.
5. Any patient without definite evidence of osseous deformity or disease until conservative measures—including the Goldthwait or Williams program, manipulation and cast, or the Ober operation—have been given a thorough trial.

It is the author's impression that, after ruling out primary neurological lesions, infectious arthritis, primary bone tumors of the pelvis, and various types of neuroses, in addition to giving the patient the benefit of a conservative program over a sufficiently long test period, the operation of choice for chronic low-back pain is arthrodesis of the joints in which the lesion can be localized. He has not had sufficient experience with the operations described by Ober, Heyman, or Freiberg to discuss their merits or indications. It is the opinion of the author that in most cases the tight iliotibial band can be relaxed by the Goldthwait-Williams type of exercises.

Sashin and Willis have each reported studies showing that degenerative changes, probably due to constant or to repeated strains and pressure effects upon the articular surfaces, result in many instances in osteo-arthritic spondylitis which may lead in a considerable number of cases to eventual bony ankylosis of the sacro-iliac joints. Of 1,559 human skeletons studied by Willis, ninety-six were completely ankylosed. Willis concludes: "From the standpoint of skeletal change the sacro-iliac joint is more frequently and more extensively involved in arthritic lesions than any other joint of the body. . . . Since the joint retains in man the anatomical features of its quadrupedal origin the mechanical stresses peculiar to the upright posture subject it to ligamentous strains. Ankylosis is a compensatory mechanism for stabilization." Sashin's conclusions are in agreement.

It is the author's custom to manipulate under anaesthesia, stretching the tensor fasciae femoris and the hip flexors in an attempt to flatten the lumbosacral spine preliminary to fusion. The spine is then fused, maintaining as nearly a normal lumbosacral curve as possible. At the time of lumbosacral fusion, the articular facets are excised and additional bone, either from the ilium or from the tibia, is used to produce a more satisfactory bone splint.

The author has purposely excluded from the list of operations the excision of portions of the intervertebral discs which may have protruded into the spinal canal. This is primarily a neurosurgical procedure. Two such operations have been reported from the University of Chicago Clinics (Bucy). Unless the annulus fibrosus has been injured posteriorly, so that nucleus-pulposus material has escaped into the spinal canal, forming cartilage-like bodies, a correction of the body posture by the Goldthwait-Williams exercises should lead to tightening up of these posterior fibers of the annulus fibrosus and restoration of the contour of the intervertebral disc. Possibly some of the patients subjected to laminectomy operations for excision of these discs could have been relieved by this more conservative program.

Surgical arthrodesis of the lumbosacral and sacro-iliac joints is indicated in cases of chronic low-back pain due to:

1. Spondylolisthesis.
2. Spondylosis (solution of bony continuity of the isthmus or pars interarticularis of the neural arch without displacement).
3. Tuberculosis of the lumbosacral or sacro-iliac joints.
4. Localized degenerative arthritis and loss of the lumbosacral intervertebral space.
5. Persistent disabling low-back pain, with or without congenital anomalies, which cannot be relieved by more conservative procedures.
6. Chronic pain following fractures or fracture-dislocations of the lumbosacral or sacro-iliac joints.
7. Chronic sclerosing osteitis involving these joints.

CONCLUSIONS

1. The vast majority of cases of low-back pain can be relieved and the patient restored to functional usefulness without operative interference.
2. Correction of bad body mechanics by physical therapy, including stretching of contracted fascia or muscles, exercises, and the use of a good spine brace over a period of time, will restore the average patient to a reasonable degree of normalcy.
3. Orthopaedic operations for the relief of low-back pain should be performed only after diagnosis has been accurately established and osseous neoplasms or neurological lesions have been excluded.

4. Pathology of the low-back region which may call for operative interference includes tuberculosis or chronic sclerosing osteomyelitis of the lumbosacral or sacro-iliac joints, primary malignant neoplasms, lesions of the spinal cord, spondylolysis, and spondylolisthesis.

5. Arthrodesing operations are contra-indicated if there is evidence of chronic infectious arthritis of the spine or of other joints.

6. Patients with a psychiatric background, who show no definite pathology in the low-back region, are considered to be poor selections for operation.

7. Patients who are seeking financial settlement because of a compensable injury are not suitable for spinal-fusion operations until after financial settlement has been made, unless there are definite osseous changes which can be demonstrated.

8. In patients for whom arthrodesing operations are planned it should be possible to localize the lesion to the joint affected. Trisacral fusions are probably rarely indicated. Multiple-joint-fusion operations are often merely shot-gun procedures.

9. Operation may be justifiably recommended for the patient with chronic low-back strain, without definite roentgenographic evidence of local pathology, which cannot be relieved by the conservative program so that the patient can resume a reasonable degree of activity, and, particularly, for patients whose economic status requires that they do manual labor in order to earn a living.

10. In the author's opinion, an arthrodesing operation is the procedure of choice.

11. The operation itself is preceded by vigorous stretching and manipulation. It is further recommended that, in fusing the spine, care be taken that the normal lumbar curve be preserved.

12. If there is a sciatic neuritis, the surgeon should excise the articular facets on both sides between the fourth and fifth lumbar vertebrae and the fifth lumbar vertebra and sacrum.

13. The orthopaedic surgeon must be constantly alert to the fact that neurological lesions or primary osseous neoplasms may produce symptoms of low-back pain and sciatic neuritis.

14. The judgment and skill of the orthopaedic surgeon may be measured by his ability to select, from the great numbers of patients who consult him because of symptoms of low-back pain, those with real indications for operative treatment. His courage may be shown either in refusing to perform an operation when it is urged that he do so and his conscience and judgment say "no", or in his determination to operate when he is convinced that only by such a procedure can the patient be cured.

15. In his own practice the author fears that he has been overconservative at times and guilty of the sin of surgical omission. And yet, in so short a series as that presented here, at least five operations have been performed which subsequently have been the cause of regret.

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OPERATIVE TREATMENT OF COCCYGODYNIA *

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The most important lesion of the coccyx is that which is usually termed *coccygodynia*, or painful coccyx. This is a condition which occurs predominantly in women, but it may occur in men. The majority of the cases are due to a definite injury, such as a fall directly on the sacrococcygeal region or a kick or blow in this region, or to some injury which occurs during labor. Occasionally the condition appears gradually and without known cause. There are, in the main, two groups of opinions as to the etiology. One group, composed largely of neurologists, believe that the condition is entirely a functional neurosis and that treatment directed at the coccyx does little or no good. The other group, composed largely of surgeons, believe that the condition is due to some pathological lesion in the coccyx, or in the coccygeal plexus of nerves which surround it, and that treatment of the coccyx should be instituted in an effort to relieve the pain. This paper is based on a series of fifteen cases of coccygodynia in which I have operated and in fourteen of which it has been possible to ascertain the result.

The symptoms vary from slight pain in the coccyx after prolonged sitting to excruciating pain and tenderness which may make sitting almost intolerable, and they are not infrequently accompanied by nervousness and irritability which cause the patients to be considered psychoneurotic. The most important symptoms are: (1) pain on sitting, which is usually more marked when sitting in a soft chair, although some patients complain of more pain when sitting on a hard chair, and all patients complain that after sitting for some time, as in a theater, the pain is aggravated; (2) a rather sharp pain on getting up from a chair or on sitting down; (3) pain on defecation; (4) pain on stooping; (5) pain on lying on the back; and (6) pain on walking. The pain is always localized in the midline at the tip of the spine, but may be referred either to the right or to the left buttock and for this reason may resemble a sacro-iliac lesion. It is caused by pressure on the coccyx or by strain on the muscles attached to the coccyx.

On physical examination, there is acute pain on direct pressure over the coccyx. There is also pain on pressure on its anterior or deep surface by rectal examination and pain on manipulation of the coccyx with the finger in the rectum. A roentgenographic examination may or may not reveal a deformity. In some of my patients the x-ray has shown the tip of the coccyx to be bent forward or deviated laterally, and in one instance

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the tip was so flexed that it pointed directly upward. In none of the patients operated upon has the roentgenogram revealed a fracture or a dislocation. At the present time I do not consider the x-ray an aid in the diagnosis of coccygodynia, except to rule out possible disease. The diagnosis is made from the history and the presence of acute tenderness when pressure is made over the coccyx. As a matter of fact, even a rectal examination is not necessary for the diagnosis, although it is usually done, presumably to rule out hemorrhoidal pain. However, I see no reason why pain due to hemorrhoids should be confused with tenderness of the coccyx.

PATHOLOGY

I have not been able to find in the literature anything concerning the pathology of coccygodynia, other than the occasional statement that the coccyx was bent or deformed or fractured. In my opinion, the gross form or position of the coccyx has little or nothing to do with the syndrome of coccygodynia, because no two coccyges which I have removed were alike and most of them would be classed as normal.

In attempting to explain the condition, I have sectioned six of the specimens and studied them microscopically, but the sections revealed apparently normal bone and connective tissue and showed no evidence of arthritis or of inflammation. The pathology is, then, unknown.

TREATMENT

In acute coccygodynia there is usually a history of a recent injury to the coccyx and the patient is suffering considerable pain and desires relief. When possible, a roentgenogram should be obtained in order to determine whether or not a fracture or displacement of the coccyx is present. If there is a definite dislocation or a fracture with marked displacement of the fragments, an attempt should be made to reduce the displacement, and local or general anaesthesia may be used. The coccyx is easily grasped between the finger in the rectum and the thumb on its posterior surface and may be manipulated as desired.

However, dislocations are very rare and in fractures there is usually little or no displacement of the fragments. In fractures without displacement the treatment is the same as though no fracture were present. Sedatives are given when necessary and a hot sitz bath is prescribed to relieve the pain. The patient is advised to get an inflated rubber ring or a horseshoe-shaped cushion to sit on and to avoid movements or positions which aggravate the pain. Strapping the low back and buttocks with adhesive may be tried, but, if this causes the pain to be more severe, the adhesive should be removed. The same is true of a girdle. In some cases a girdle or corset gives some relief, but in others it causes the pain to be more severe. If the pain is very severe, the patient should be advised to remain in bed for a few days or until she can be up and about with comparative comfort.

A coccygodynia may be said to be chronic when the pain has persisted over a period of two months or more. It is the chronic coccygodynia with which this paper is especially concerned. At present there is wide divergence of opinion concerning the best form of treatment for this condition.

Many patients with a chronic coccygodynia are quite nervous or definitely psychoneurotic, and many believe that coccygodynia is a functional disorder and that treatment directed at the coccyx is unwise. A certain percentage of these patients get well under psychotherapy if it can be continued long enough. The same is true of any other form of therapy, or of no therapy. In many patients the pain eventually disappears, but it may recur.

For chronic coccygodynia, Baastrup recommends deep x-ray therapy and states that ten out of fifteen patients were cured by this treatment. Injections of alcohol into the painful area have been used for thirty years and are still recommended (Yeomans), but they have not gained popular favor and Gant definitely states that in his hands the injection treatment was not successful. Kleckner injects 5-per-cent. quinine and urea hydrochloride, and Mandl uses forty cubic centimeters of .5-per-cent. novocain. Recently Suermondt has injected forty cubic centimeters of 1-per-cent. novocain into the sacral canal and the injection is repeated at intervals if necessary.

When consulted by a patient with chronic coccygodynia, I am interested in the course and severity of the pain and the patient's reaction to it. If the pain is not very severe or is becoming less severe and if it does not greatly inconvenience the patient, I give her a mild sedative or small doses of salicylates, have her get an inflated rubber ring to sit upon, advise her to avoid, if possible, movements or positions which aggravate the pain, and tell her that, if the pain should become sufficiently troublesome to warrant an operation, the coccyx can be removed with the expectation that the pain will be relieved permanently. However, most of these patients never come to operation.

If the pain is severe and causes great inconvenience to the patient, I try the line of treatment just described for a few weeks and, if there is no improvement, advise removal of the coccyx. The operation may be fairly difficult and I think that it should be performed with meticulous care.

TECHNIQUE OF THE OPERATION

The patient enters the hospital on the day preceding the operation and is started on a low-residue diet.

The operation is performed under general anaesthesia with the patient prone upon a table, one end of which may be lowered so that the thighs may be flexed about 30 degrees.

I have not tried the transverse incision; I use a midline vertical incision about two and one-half inches long, the middle of the incision being

over the sacrococcygeal articulation and the lower end well removed from the anus. This incision is carried down to the bone throughout its length, and it is usual to find the coccyx pointing directly downward,—that is, away from the skin incision. By sharp dissection, as much as possible of the posterior surface of the coccyx is exposed. If it is bent forward, the tip cannot be exposed until later.

After the posterior surface of the coccyx has been well exposed, the posterior part of the intervertebral disc between the coccyx and the sacrum is cut with a knife. The ligaments between the inferior part of the sacrum and the first segment of the coccyx are then carefully cut away from the coccyx; in so doing the operator should keep close to the bone. Usually at this point a small artery is cut on each side of the bone and this must be clamped in order to secure a clear field.

After the lateral part of the first segment is freed, it is grasped with a towel clip and, by twisting it from side to side, the remaining attachments to the sacrum are put on tension and cut with a knife. The coccyx is then pulled gently backward—that is, in the direction tending to pull it out of the wound—and, by sharp dissection with a knife, the aponeurotic fibers are cut from its lateral borders and the tissues are cut from its deep surface. This dissection is done a little at a time, first on one side and then on the other. It is to be remembered that the rectum lies very close to the deep surface of the coccyx and for this reason the knife is kept against the bone. Some surgeons have an assistant keep his finger in the rectum during this part of the operation. I cannot see what good this does, and I should be afraid that the assistant might push the wall of the rectum backward and endanger both the rectum and his finger. When the tip is reached, the strong fibers attached to it are cut transversely and the entire bone is removed in one piece. On three occasions, where the tip has been curved forward, I have severed the coccyx near its end and have then removed the tip separately. This was done accidentally, but it is the easiest and safest way to remove a tip which is anteverted.

After the coccyx has been removed, the distal end of the sacrum is found to be quite prominent. This prominence is removed by beveling the posterior margin of the lower end of the sacrum or, if necessary, by removing some of the entire thickness of the bone and beveling what is left, the object being to leave nothing that will be irritated by pressure from without.

An effort is then made to restore the posterior pelvic floor by placing from two to four mattress sutures of chromic catgut in the aponeurotic tissues which have been cut from the margins of the coccyx and drawing them together in the midline to obliterate the dead space and to cover the stump of the sacrum. The subcutaneous tissues are then closed snugly with No. 000 plain catgut, the skin is closed with silk, and a small dry dressing is applied.

The dressing is not sealed with collodion nor is the buttock strapped, but the nurse is cautioned to watch the patient and to change the dressing

if it should become soiled. The constipating diet is continued and on the fourth day the patient is given an enema, after which the dressing is changed. The sutures are removed on the fifth or sixth day and the dressing is kept on about a week longer.

Most of the patients leave the hospital in six or seven days and begin to walk a little. Their activity increases as the wound heals firmly, and there is no after-treatment.

An immediate cessation of pain is not to be expected, because the painful coccyx has been replaced by a fresh operative wound. The average patient is quite active within three or four weeks after the operation, but still has some pain on sitting. This usually disappears within a month or two, but in an occasional case it is three or four months before the patient can attend a theater with comfort.

CLINICAL RESULTS

During the past six years I have operated upon fifteen patients, using the technique described. There were fourteen women and one man in the series and their ages ranged from seventeen to fifty-eight years. Eleven of these patients attributed their condition to a fall on the end of the spine or tail bone; one patient was kicked; one, who was a stenographer, believed that her symptoms were due to sitting all day in an uncomfortable office chair; and in two cases the symptoms appeared after normal deliveries. The symptoms had been present for from three months to twelve years and the average duration of symptoms was a little over two years.

As to the results of the operation, it has been possible to trace fourteen of these patients and all except two have been completely relieved of their coccygeal symptoms. One of these was operated upon only one month prior to this report, at which time she was convalescing normally with the expectation of obtaining complete relief within another month or so. The other is a woman, fifty-eight years of age, who was operated upon five months before this report and whom I have not seen since she left the hospital eight days after the operation. She writes that her symptoms, which were quite severe, have almost entirely disappeared, but that she still has a little pain after sitting for a long time in one position.

I have not been able to trace one of the clinic patients. She was from out of town and was operated upon in 1933. Six months after the operation her husband wrote that she was worse than before the operation, but, as she also complained of pain in the right lower quadrant of the abdomen before the operation, I do not know whether her later symptoms were due to this or to the coccyx, and repeated letters have not been answered.

Two of the patients have borne one or more children since the operation and have had no difficulty.

One patient also complained of severe pain and tenderness over the first and second sacral spinous processes. Therefore, the incision was

extended upward and those spinous processes were removed with subsequent disappearance of the pain.

There were two postoperative complications. One patient began to menstruate on the day after the operation and the skin wound became red and inflamed. Two days later, I removed the sutures and the skin edges separated. The wound took about a month to heal. Now I do not operate on the coccyx during the week before a menstrual period is expected.

The other complication was due to poor surgical judgment. Seventeen days after the coccyx was removed, a large Bartholin-gland cyst was excised by a gynecologist. Six days later, the coccygeal wound was opened and a considerable amount of pus was evacuated. Later a rectal fistula developed and of course I was accused of having nicked the rectum. However, the coccygeal wound healed and, when the rectal fistula was excised some months later, the tract led to the labia and there was no tract to the sacrococcygeal region, so I was exonerated.

CONCLUSIONS

1. Most cases of acute and of mild chronic coccygodynia respond to conservative treatment.

2. In severe chronic coccygodynia, excision of the coccyx, followed by careful restoration of the pelvic floor, may be expected to relieve the symptoms and to cause no disability.

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RESULTS OF FASCIOTOMY FOR THE RELIEF OF SCIATIC PAIN † *

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This report is concerned with an analysis of the results of division of the fascia lata for the relief of sciatic pain in forty-nine patients who were operated upon at the New York Orthopaedic Dispensary and Hospital between June 1, 1932 and February 10, 1936. In ten cases, the operation was done on both sides, and in two it was repeated on the same side because the first procedure apparently was incomplete, making in all sixty-one operations on fifty-nine extremities. The technique in all cases was that described by Ober. Twenty-three patients were males and twenty-six were females. The average age of the group was thirty-seven years, and the average period for which they were observed after operation was sixteen months. In only nine cases was the follow-up less than one year, and the majority of these were failures, in which the results would not have been influenced by longer observation.

The patients all had pain of a similar distribution, starting in the sacro-iliac region or buttock and radiating down the posterior aspect of the thigh. In many it continued along the outer side of the leg to the ankle. Several stated that the pain was present in the posterior gluteal region and that it skipped the thigh, appearing again in the leg. In all instances it was severe. Although pain of this character usually is called sciatica, it should be realized that this name applies to a symptom only, which may be due to a number of different causes, and that it does not necessarily imply an inflammation of the sciatic nerve.

In addition to having sciatic pain, these patients also exhibited a tightness of the fascia lata and iliotibial band. This was demonstrated by the Ober test, in which the patient is placed on his side with the hip and knee flexed. The uppermost extremity is then extended and abducted with the knee flexed, and then allowed to adduct in the extended position. If the fascia is taut, adduction is limited and the fascia stands out as a definite band. In the majority of cases, flexion of the hip with the knee extended was limited and painful. In a few cases, hyperextension of the thigh also was limited. The interesting observation was made that in several patients the Ober test varied from one day to another. It is believed that in these cases the tightness of the fascia was due to muscle contraction. Real structural contracture probably is a later occurrence, after the muscles have been in spasm for a long time.

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The mechanism by which a taut or contracted fascia lata causes sciatica has not been satisfactorily explained. It is true that in many individuals who have not had pain the Ober test is positive. Nor has any explanation been given for the fact that patients with a markedly contracted fascia lata, resulting from paralysis in poliomyelitis, do not have pain.

Backache was also present at some time in most of these patients. By this is meant pain extending across the whole lumbosacral region in contradistinction to the pain on one side, which is a part of the sciatica. As a rule, the low-back pain preceded the sciatica and often disappeared when the latter began.

It is of the greatest importance in all cases of sciatic pain to do a careful neurological examination in order to rule out the presence of a spinal-cord tumor or possibly a protruding nucleus pulposus. Such an examination was made in all of these patients by a competent neurologist, usually without significant findings. One man had no patellar reflexes and several patients had absent or diminished ankle jerks. In a few there was slight hypaesthesia over the outer side of the leg. A spinal puncture was done in a number of cases, with normal results. However, in one patient, seen after this series was concluded, a high total protein in the spinal fluid was the means of discovering a cholesteatoma of the spinal cord. One patient in this group, after a thorough examination at a neurological hospital, was said to have a chronic meningomyelitis, in spite of which her sciatic pain was cured by fasciotomy.

Lumbosacral roentgenograms were taken of all the patients and, with one or two exceptions, they revealed variations in the lumbosacral joints which might be supposed to cause instability and to predispose to pain. These variations included exaggerated lumbosacral angle, anteroposterior or asymmetrical articulations, posterior displacement of the fifth lumbar vertebra, transitional lumbosacral vertebra, and thin intervertebral disc. Several patients had evidences of arthritis in the lumbosacral spine.

The operation was performed through an almost transverse incision from below the anterior superior iliac spine to a point behind and above the greater trochanter. The fascia lata was thoroughly sectioned, including the septa between the muscles. The patients were allowed up in from seven to ten days.

Because of certain other operations which were done on some of the patients, it is necessary to divide them into three groups for purposes of analysis: (1) those on whom a fasciotomy alone was performed; (2) those who previously had had a fusion of the lumbosacral spine and who then had a fasciotomy for continued sciatica; and (3) those on whom some other operation, usually a spine fusion, was done at or about the same time as the fasciotomy.

Group I—Fasciotomy Alone

There were twenty patients in this division. The average age was forty years, and they were about equally divided as to sex. The sciatica

was unilateral in nineteen and bilateral in one, and had been present from four weeks to eighteen years before operation; in eleven cases it was of more than one year's duration. Twenty-one operations were performed. Complete relief of sciatica followed the operation in thirteen patients. Two complained of slight pain afterward and five obtained little or no relief. Seven patients had no backache either before or after the operation. Five had back pain before operation, which continued afterward, and four others were relieved of backache by the operation. However, in four patients who had had no back pain before the operation, pain developed after fasciotomy. The results of fasciotomy, considered from the standpoint of sciatica alone, were classed as excellent in nine, good in six, and unsatisfactory in five. It is interesting that in one patient who obtained complete relief from a severe left sciatica in October 1935, right sciatica developed in November 1936, which was also immediately and completely relieved by fasciotomy.

In examining the five cases with poor results, it was found that in one case, that of a physician, thirty years of age, there was not only failure to obtain relief from the sciatica, but also a return of the back pain. This patient had a posterior displacement of the fifth lumbar vertebra, and both the sciatica and the back pain were cured later by a spine fusion. In another patient with a posterior displacement of the fifth lumbar vertebra, there was diminution of the sciatic pain (which he estimated to be 75 per cent.) for several months, but then both the back pain and the sciatica returned. A third was a compensation case and the patient refused to return to the Clinic. Two patients were seventy-five and eighty years of age respectively. Both had arthritis and probably were not good subjects for the procedure.

Group II—Spine Fusion Followed Later by Fasciotomy

Twenty patients were included in this group, whose average age was thirty-three and five-tenths years. There were twelve unilateral and eight bilateral operations. The procedure was repeated in one case. These patients presented, on the whole, a more severe type of lumbosacral abnormality, and eighteen had more or less severe back pain in addition to the sciatica. As a result of the spine fusion, the back pain was relieved in seven cases, but the sciatica continued in all. Before the fasciotomy was performed, the sciatica had been present for from three months to sixteen years, and in sixteen patients, for more than one year. At the time of the last examination, which averaged seventeen months after operation, the sciatica still was severe in fifteen, slight in one, and absent in four. Back pain still was present in eleven. The results were excellent in four, good in one, and unsatisfactory in fifteen.

Among the fifteen failures, there were two cases of pseudarthrosis, or imperfect spine fusion, which probably accounted for the sciatica. Ten of these patients obtained partial or complete relief, lasting from two to sixteen months. The standard by which these cases are judged as failures,

therefore, is a severe one. It is believed that in these cases such a simple operation was worth while, even though the relief from pain was not permanent. This group also emphasizes the importance of a long follow-up study of this condition. It is difficult to decide whether the relief from back pain in some of these cases was due to the spine fusion or to the fasciotomy, in spite of the fact that in the majority an appreciable interval occurred between the two.

Group III—Fasciotomy Combined with Another Operation

Very little can be learned about the effect of fasciotomy in the nine patients who comprised this group, because of the fact that a spine fusion was performed either at or about the same time in eight cases, and a sacroiliac fusion was done in one. The average age was thirty-five. There were six females and three males, and the sciatica was unilateral in eight and bilateral in one. Nine operations were performed. Five patients had back pain in addition to sciatica before operation. Six patients obtained complete relief from sciatica; one continued to have slight pain; and two still had severe pain after operation. Back pain was severe in three, slight in one, and absent in five following the operative procedures. One failure was attributable to infection and consequent failure of the spine-fusion operation. It is probable that in two cases the fasciotomy would have been a failure, because the sciatica continued after it was done, and disappeared after a spine fusion a short time later.

In all of the groups, relief from the sciatic pain usually was prompt and often dramatic in its suddenness. In few cases was the improvement gradual. A study of the effect of the operation on back pain, as distinguished from sciatica, shows that in twelve patients, who had such pain previously, there was none after operation; in twenty no relief from back pain was obtained; and in four, who had no back pain before fasciotomy, it developed afterward. Furthermore, it is quite probable that the relief from back pain obtained in some of the twelve cases was attributable to a spine fusion rather than to the fasciotomy.

Search has been made for some common factors in the successful results which would give us a clue in selecting those patients most likely to be benefited by this procedure, but none, other than the taut fascia lata, has been found. It would seem that in cases of severe backache and sciatica with pronounced lumbosacral abnormalities, as well as in cases of advanced arthritis, good results are least likely to be obtained, but to this there are several notable exceptions. There was no significant difference in the duration of the pain between the successful cases and the failures. That the operation is of great value in certain cases is unquestionably true. Further study of this problem should help us to determine in advance which cases are suitable.

SUMMARY

The results of fasciotomy performed on forty-nine patients with

sciatic pain, whose average postoperative observation period was sixteen months, were as follows:

1. In the group who had a fasciotomy only, excellent or good results were obtained in 75 per cent.; failure resulted in 25 per cent.

2. Of twenty cases in which lumbosacral fusion had failed to cure the sciatica, subsequent fasciotomy resulted in failure in 75 per cent. However, many of these patients obtained temporary relief of from two to sixteen months.

CONCLUSIONS

1. Fasciotomy cannot be relied upon to cure low-back pain as distinguished from sciatica.

2. Although the mechanism by which fasciotomy cures sciatica is not known, the operation has proved of value and further study should throw more light on the selection of suitable cases.

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THE MECHANICS OF THE LUMBOSACRAL AND SACRO-ILIAC JOINTS *

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The fundamental principle of the orthopaedic surgeon, whether he is working on joints or fractures, is the prevention of deformities, and his aim is the attainment of the optimum position for function. The optimum position for function is entirely dependent on the shape and range of motion of the joints in question and on the shape and position of the adjacent joints. For example, the best position for arthrodesis of a tuberculous knee with a normal hip joint above it is entirely different from that required if the hip has limited motion. The optimum position for an arthrodesed hip is dependent on the amount of compensatory motion in the spine. Likewise the optimum position for function of one part of the spine is equally dependent on the position and condition of the rest of the spine. The enormous compensatory mechanism of the spine as a whole has dimmed the importance of the position of one section of the spine in its relation to the other parts.

FIG. 1

Lateral views of three sacra, showing the variety in the size and shape of the sacro-iliac joints. All the joints are roughly auricular in shape,—broadest in the upper part, narrowest in the middle portion, and widening slightly in the lower part. In the upper part the width of the joint is about one-half and in the lower part about one-third, or less, as large as the longest diameter.

Willis and many others have pointed out the many anatomical variations in the different sections of the spine and it is not necessary to mention these, except to point out that, since no two spines are anatomically alike, each one must be judged on its own individual structure.

Whatever the anatomical shape of the bones may be, there is always an optimum position for function for that particular anatomical variety of spine, and that position is the one in which none of the spinal joints are either at the point of extreme flexion or of extreme extension. The range of motion from this optimum position is entirely dependent on the anatomical structure of the bones. If, for a period of years, the habitual

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 14, 1937.

position of use of the lumbar spine has been that of extreme extension—a position which is so common in the growing period of life—there will be, according to Wolff's law, changes in the shape of the bones as well as in the ligaments and muscles which are attached to the pelvis and the hip joints. A method of treatment, therefore, which corrects only one deformity and leaves the rest of the spine uncorrected is not following out the orthopaedic and surgical principles which should be the basis of all of our work.

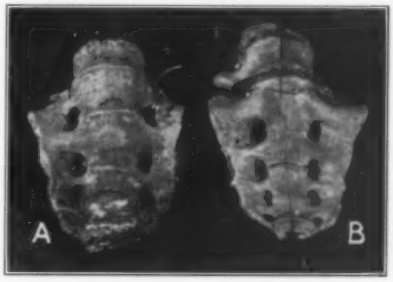

FIG. 2

Photograph of sacra from the anterior surface. Sacrum *A* is roughly rectangular and sacrum *B* is more triangular. In the latter, the width between the wings or the upper part of the sacrum, on the external side of which are the sacro-iliac joints, is much more than that in the middle of the body of the sacrum. As a result, the sacro-iliac joints are in an oblique plane. In the former, the width between the wings and that in the middle of the sacrum is about the same. This means that in this type of sacrum the sacro-iliac joints are nearly vertical and are consequently more unstable.

As has been stated, there can be no degree of curve that is the correct one for all spines and also the curve of any one part of the spine is greatly affected by the curves of the other parts of the spine. It is a simple matter to teach an individual to flatten the curve of the lumbar spine, but there may be little or no difference in the strain on the lumbar region if the thoracic and cervical curves are not corrected at the same time. Flattening the lumbar spine is always accomplished by changing the inclination of the pelvis. Since a change in the inclination of the pelvis affects the mechanics of the sacro-iliac joints, it is well to consider the mechanics of these joints at this point.

The sacrum has always been considered as an inverted keystone to the pelvic arch. The sacro-iliac joints are described as auricular-shaped, broadest in the upper part, narrowest in the middle, and widening slightly in the lower part. (See Figure 1.) The longest diameter of the joint surfaces is parallel to the body of the sacrum. The shortest is from the anterior to the posterior surface of the sacrum. At the upper end of the sacrum the shortest diameter of the joint is about one-half as long as the longest diameter, while in the middle of the joint it is one-third or less. The surfaces of these joints are covered with articular cartilage, and there are small prominences and hollows which articulate with hollows and prominences in the opposing joint surfaces of the ilia.

Sacra viewed from the front show considerable variations in shape. Some are roughly rectangular (Fig. 2, *A*) and others are more triangular (Fig. 2, *B*). In the latter the wings of the sacrum, on the external side of which are the sacro-iliac joints, are wider than the lower part and, as a result, the sacro-iliac joints are in an oblique plane. In the former the joints are more nearly vertical and, in consequence, are more unstable. The direction in which the articular surfaces of the sacro-iliac joints face

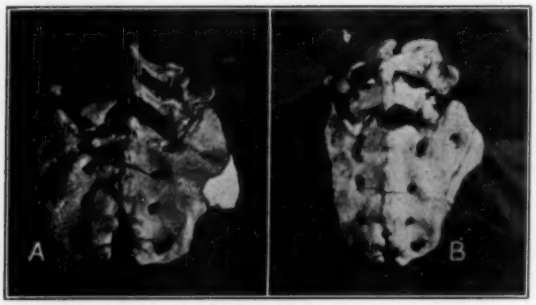

FIG. 3

Photographs of a sacrum in the horizontal (*A*) and in the vertical (*B*) positions, showing the difference in direction in which the articular surfaces face. In the horizontal sacrum the surface of the joint faces outward, slightly upward, and backward, making a perfect inverted keystone to the pelvic arch. In the vertical sacrum the surface faces outward, slightly downward, and backward, thus making a true keystone to the arch. In the horizontal position the sacro-iliac joints support the weight of the body on their narrowest diameter; in the vertical position, on their longest diameter.

is of much importance and is very greatly affected by the position and inclination of the pelvis. When the pelvis is in the horizontal position (Fig. 3, *A*), the articular surfaces face outward, slightly upward, and backward, making a perfect inverted keystone to the pelvic arch. However, when the pelvis is in the vertical position (Fig. 3, *B*), the articular surfaces face outward, slightly downward, and backward, thus making a true keystone to the pelvic arch. In the specimen shown in Figures 4-A and 4-B a piece of wire was placed on the long diameter of the sacro-iliac joint and a nail on the short diameter at its widest point. In the horizontal position of the sacrum (Fig. 4-A), the sacro-iliac joints support the weight of the body on their narrowest diameter. In the vertical position (Fig. 4-B), the longest diameter takes the weight of the body.

FIG. 4-A

FIG. 4-B

Roentgenograms of a sacrum in the horizontal (Fig. 4-A) and in the vertical (Fig. 4-B) positions. A piece of wire has been placed on the long diameter of the sacro-iliac joint and a nail on the short diameter at its widest point. This shows that in the horizontal position of the sacrum the weight of the body is supported on the narrowest or shortest diameter of the sacro-iliac joint. In the vertical position the weight of the body is supported on the longest diameter of the joint.

FIG. 5-A FIG. 5-B

Lateral roentgenograms of a bone specimen in which a wire has been placed, outlining the anterior edge of the sacro-iliac joint. Note that the sacro-iliac joint is roughly triangular in shape. With the sacrum in the horizontal position (Fig. 5-B), the base of this triangle is facing forward or even downward. In the vertical position (Fig. 5-A), the base of the triangle is more nearly upward.

When the pelvis is in the horizontal position, it must have rotated forward on an axis, the center of which is in the acetabulum or hip joint. In such a position the sacro-iliac joints have become anterior to the center of the acetabulum. When the pelvis is in the vertical position, these joints are above or posterior to the center of the acetabulum.

If we consider the sacro-iliac joints as triangles with two long sides and a narrow base, a horizontal sacrum (Fig. 5-B) means that the base of the triangle is facing forward or even downward. With the sacrum in the vertical position (Fig. 5-A), the base of the triangle faces more upward and thereby tends to act as a more effective keystone. When the sacrum is in the horizontal position, it has rotated forward on an axis, the center of which is in the acetabulum or the heads of the femora. In such a position the sacro-iliac joints are above or anterior to the center of the acetabulum or the heads of the femora. With the sacrum in the vertical position, the sacro-iliac joints are above or posterior to the center of the acetabulum and heads of the femora. Thus it can be seen that, from the weight-bearing and functional point of view, the markedly forward inclination of the sacrum cannot be an optimum position, because it must increase the strains on the sacro-iliac joints. Such a position also creates an equal, if not greater, strain on the lumbosacral and low lumbar articular facets. With the sacrum horizontal (Fig. 6-B), the lumbosacral joints are anterior to the center of the pelvic rotation in the acetabulum; this position necessitates a compensatory extension of the lumbar spine, the amount of which is dependent on the anatomical structure. With the sacrum vertical (Fig. 6-A), the lumbosacral joints are above or posterior to the center of rotation.

Figures 7-A and 7-B are roentgenograms of a patient who complained of backache in the low lumbar region as well as, at times, in such other parts as the thoracolumbar and midthoracic regions. A lateral view (Fig. 7-A) shows a moderately horizontal sacrum, and a marked lumbar curve with the spinous processes almost, if not completely, in contact and the articular facets jammed into the position of extreme extension, which means a narrowing of the intervertebral foramina. With such a potential of trouble, it is understandable how extra strain might cause pain referable to the sacro-iliac or the lumbosacral nerves. It will also be noted that the compensation for the position of the sacrum and the lumbosacral curve has caused the ribs to be in nearly a vertical position,—a condition which occurs with an increased thoracic curve, an increased cervical curve, and a forward position of the head. All of these compensatory curves have a very definite part in the strain on the low back. The treatment, therefore, must not only consist of flattening of the lumbar curve or the removal of strain by a fusion operation, but it must be aimed at correcting the mechanics of the whole body in order to relieve the strain on the lumbar and sacro-iliac joints. This patient was sixty years old. Figure 7-B, taken with the thighs flexed on the abdomen, shows how much motion can be obtained in the lumbosacral region. The lumbar curve is straight and the spinous processes are well apart. The intervertebral discs are sym-

FIG. 6-A

FIG. 6-B

Lateral roentgenograms of a bone specimen, showing that the lumbosacral joints in a horizontal pelvis (Fig. 6-B) are anterior to the center of pelvic rotation,—a position which necessitates a compensatory extension of the lumbar spine. With the pelvis vertical (Fig. 6-A), the lumbosacral joints are above or posterior to the center of rotation. This results in a decrease of the lumbar curve. (*Courtesy of the New England Journal of Medicine.*)

FIG. 7-A

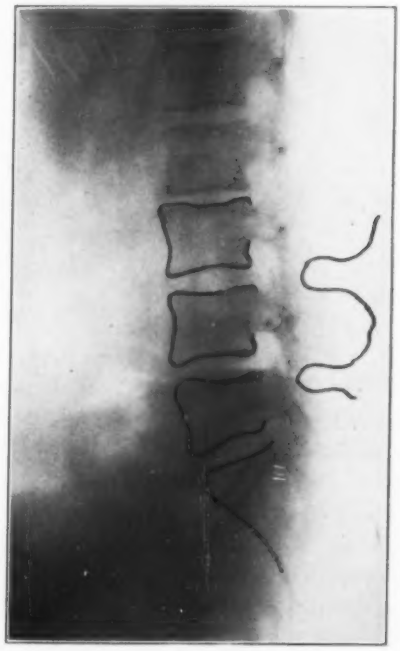

FIG. 7-B

Lateral roentgenograms of a patient who complained of backache and, at times, of pain in other parts, such as in the thoracolumbar and midthoracic regions.

Fig. 7-A: Note the horizontal sacrum and the marked lumbar curve with the spinous processes almost, if not completely, in contact. The articular facets are jammed into a position of extreme extension, which means a narrowing of the intervertebral foramina. Such a position is a potential of trouble if the spine undergoes an unusual strain.

Fig. 7-B: This shows how much motion in correction can be obtained in the lumbosacral region even in a patient sixty years old. This roentgenogram was taken with the thighs flexed on the abdomen. Note that the lumbar curve is straight and the spinous processes are well apart. The intervertebral discs are more symmetrical. The weight in this position would be carried on the discs and not almost entirely on the facets.

metrical in shape. In this position the weight of the body is carried on the discs and the articular facets act in their true capacity as stabilizers and do not carry almost all of the weight.

In conclusion, the criterion of whether any one type of treatment is efficient should not be only the relief of symptoms, because this can be obtained by that treatment with which the physician is most familiar. The criterion should be the same as we hold ourselves to in fracture work,—namely, has the treatment been successful in obtaining the best position for function that is possible for the entire anatomical structure involved?

ROOT PAIN RESULTING FROM INTRASPINAL PROTRUSION OF INTERVERTEBRAL DISCS

Diagnosis and Surgical Treatment *

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This report is based on a careful study of the records of fifty consecutive patients who have been operated on at The Mayo Clinic for protrusion of one or more intervertebral discs, producing either root pain or symptoms and signs of compression of the spinal cord. Prior to January 1, 1935, only eleven patients were operated on for protruded discs, or 2.3 per cent. of a series of 471 patients who were operated on for tumors of the spinal cord. Between January 1, 1935, and November 1, 1936, thirty-nine patients underwent laminectomy for abnormal protrusion of an intervertebral disc into the spinal canal.** During this same period, sixty-two additional patients were operated on for tumors of the spinal cord. Thus, of a series of 572 cases of verified intraspinal lesions that were causing compression on the spinal cord or roots, in fifty cases the compression was due to a protruded disc.

The part played by protruding discs in the production of neurological symptoms is receiving increasingly wide recognition. There has been a tremendous change in the percentage of protruded discs as compared with that of neoplasms of the spinal cord. This change has been brought about by increased ability to diagnose such lesions early. In this regard, the use of lipiodol in the intraspinal subarachnoid space in cases of intractable sciatica has contributed largely to the detection and localization of such lesions.

The whole-hearted cooperation of the orthopaedic consultants at the Clinic has made this report possible, since we in the Section on Neurological Surgery are dependent on them for the selection of many of these cases for neurological investigation and their opinions have aided us in avoiding the indiscriminate use of lipiodol intraspinally.

REVIEW OF LITERATURE

Goldthwait [9], in 1911, apparently was the first in this country to direct attention to the possible rôle of the intervertebral disc in the production of symptoms of "lumbago", "sciatica", and compression of nerves within the spinal canal. Middleton and Teacher [14], of Glasgow, in the same year reported the post-mortem findings in a case in which the symptoms

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 14, 1937.

** From November 1, 1936, to June 18, 1937, forty-five additional patients were operated on for protruded discs.

were due to protrusion of an intervertebral disc into the spinal canal. The work of Schmorl [21] on the pathology of the disc is classic, and his researches on the subject are without parallel; he, however, felt that the extruded disc did not produce neurological symptoms.

Adson [4], as early as 1922, in this Clinic performed laminectomy and removed a protruded disc which had been pressing on the cervical portion of the spinal cord with the consequent production of neurological symptoms in all four extremities. This patient is still alive and earning his living as a barber fifteen years after the operation. This case, incidentally, was included in a paper [1] on tumors of the spinal cord which was presented before the Seattle Surgical Society on January 8, 1925, and in which a drawing of the operative exposure of the disc was included.

In 1928 Stookey [22] reported seven cases of compression of the cervical portion of the spinal cord, resulting from protrusion of cervical intervertebral discs. In 1929 Dandy [8] reported two cases in which he had operated for protrusion of a lumbar intervertebral disc with paraplegia. He stressed the importance of trauma in the production of these lesions and the benefits to be derived from laminectomy and removal of the protruded fragments of disc. Bucy [5], in 1930, reported the case of a patient who had a tumor of one of the lumbar discs. This protrusion was removed and Bucy felt that the tissue represented a true neoplasm. Hawk [11], in June 1936, added ten cases to the literature and analyzed fifty from previous reports.

Neurosurgeons at The Mayo Clinic have for many years removed at the time of laminectomy extradural fibrocartilaginous masses from the spinal canal in cases in which the diagnosis was tumor of the spinal cord. It has been only in recent years, however, that we have come to look on these masses, not as neoplasms, but as abnormal protrusions of a normal unit of the spine,—namely, the intervertebral disc. In 1924 such a specimen, submitted to the surgical pathologist, was reported by him to be "fibrochondromatosis of the intervertebral disc". Formerly, these patients were operated on so infrequently and so late in the course of the process (in contrast to today) that at the time of operation the clinical picture was that of compression of the spinal cord such as is caused by a neoplasm. These cases were then usually classified as extradural tumors of the spinal cord. The work of Mixter and Barr [17], in 1934, served to focus attention on these cases, and since then the condition has been recognized earlier and operation is performed before the classic symptoms and signs of a neoplasm affecting the spinal cord develop. The paper by Mixter and Ayer [16] in 1935 again served to emphasize the frequency of occurrence of protruded discs with the production of root pain.

ETIOLOGY OF PROTRUDED INTERVERTEBRAL DISCS

It is our opinion at the Clinic that abnormal protrusion of an intervertebral disc into the spinal canal is, in the great majority of cases, the result of trauma. In this opinion we are in accord with most authors who

have written on the subject. We feel that the restraining annulus fibrosus is ruptured or weakened by undue stress and strain, whereupon the nucleus pulposus protrudes or herniates into the spinal canal with subsequent encroachment on the domain of the intradural or extradural nerve structures. Ribbert [20], in 1895, by a set of ingenious experiments, produced herniation of the nucleus pulposus anteriorly in rabbits by puncturing the intervertebral discs.

That puncture of the disc occurs only in experimental procedures on animals should not be entertained, for reports [15,19] have appeared in which attention has been called to the occurrence of this complication in the course of lumbar puncture either for diagnostic, therapeutic, or anaesthetic purposes. We have had no such case at the Clinic, but that this is a possibility can easily be seen. Protrusions of the discs that are recognized clinically and for which laminectomy is indicated occur posteriorly. That the disc may protrude anteriorly, however, cannot be denied. Whether or not such a lesion would produce symptoms, we are not prepared to say. Certainly, one would expect the protrusion to occur most often posteriorly because of the mechanical forces at work at the time of injury to the spine. Most of the injuries occur when the spine is in flexion. Thus the posterior portion of the annulus fibrosus is subjected to undue stress at the same time that the vertebral interspace is being narrowed anteriorly. This results in a squeezing of the compressible nucleus pulposus backward against an overstretched and weakened barrier. The barrier (annulus fibrosus) may not give way the first time, but, if subsequent injury occurs, extrusion of the nucleus, or indeed of most of the disc, may result. Overstretching may lead to degenerative changes, with subsequent protrusion of the disc without the occurrence of precipitating trauma immediately before the onset of symptoms.

PATHOLOGY OF PROTRUDED INTERVERTEBRAL DISCS

Dr. Kernohan [12] has been kind enough to collect the operative specimens obtained in this series of cases and has given us a report of his findings on microscopic study of the tissue.

Although there have been a variety of findings microscopically, the picture is essentially one of degeneration of the fibrocartilaginous constituents of the normal disc. The degenerative process may be slight or marked. Calcium, and even bone, may be found in the protruded portion of the disc. In some specimens, remnants of notochordal tissue are seen.

SYMPTOMS OF PROTRUSION OF INTERVERTEBRAL DISCS

The symptoms of protrusion of intervertebral discs into the spinal canal vary greatly, but the chief symptom is root pain and this pain is often unilateral. The pain may be referred to the peripheral distribution of one spinal-nerve root, or it may involve more than one peripheral segment, depending on the size and the location of the protrusion. For those not thoroughly familiar with neurological terms, "root pain" is defined as

pain which begins within or near the spinal cord and is projected peripherally to that part of the body or extremity innervated by the nerve fibers which leave the cord through the spinal-nerve root emerging at that level. The pain is often described as "sharp", "shooting", or "like an electric shock", and it is usually brought on or made worse by coughing, jarring, or sneezing. It is often precipitated by putting the particular nerve involved on tension, as by bending the neck or back. This phenomenon likewise accounts for the positive Kernig and Lasègue signs which are elicited when the roots of the sciatic nerve are compressed by an extruded disc. Intractable sciatica is often an expression of root pain, and frequently sciatic pain is the result of protrusion of an intervertebral disc.

In some cases the pain caused by a protruded disc does not suggest pain of the root type. Occasionally, patients complain only of "backache" or of "lumbago". The backache is often in the lower part of the back and simulates all the conditions, neurological and orthopaedic, which may occur in the region of the lumbosacral joint and the sacro-iliac synchondroses. Sometimes, though rarely, there is little or no pain and numbness or weakness is the complaint, which should attract the examiner's attention to possible involvement of the spinal cord or of its peripheral nerves. Paralysis of one or more extremities or of the vesical or anal sphincters is usually a late development, and one should strive to make an accurate diagnosis and remove the cause before such serious symptoms develop. In one of our cases at the Clinic, paralysis of the lower extremities, the bowel, and the bladder developed within three months of the onset of pain. The process was so rapid, in fact, that a malignant neoplasm was suspected prior to the introduction of lipiodol and fluoroscopic observation. In another case (Fig. 1), that of a man with a protruded cervical disc, a transverse lesion of the cord with loss of sphincteric control developed within a month from the date of onset of symptoms.

There are no physical, neurological, or orthopaedic signs which are found alone in cases of protrusion of intervertebral discs. All of the known signs may also be found in other conditions.

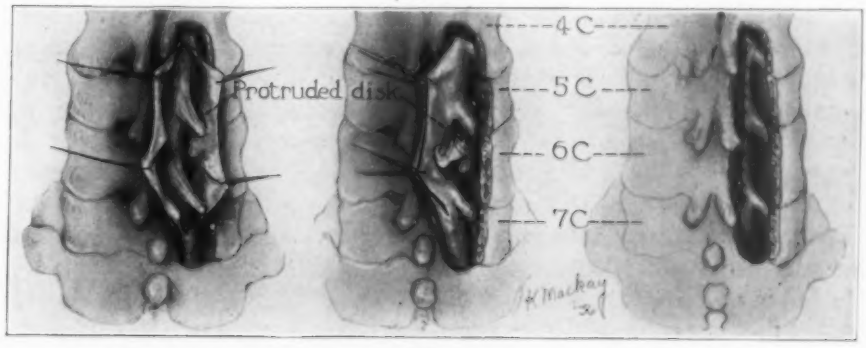

FIG. 1

Removal of protruded fifth cervical intervertebral disc, resulting in cure.

ROENTGENOGRAPHIC DIAGNOSIS

The roentgenographic diagnosis and localization of protrusion of an intervertebral disc into the spinal canal is dependent on the use of a radiopaque oil which is injected into the subarachnoid space. An analysis of the changes observed in the plain roentgenograms in this series of fifty cases further substantiates our opinion and that of others [10, 16] that ordinary roentgenograms are of little value in the diagnosis. It would seem that in any condition in which trauma is such a common etiological factor there should be visible in plain roentgenograms some alteration in bone or joint structure to denote the site of the lesion. For this reason, it is interesting to review the changes most frequently observed in the spine, as regards their relation to the site of the protruded disc, and to see wherein they may be either of some value or else misleading.

There were fourteen cases in which the plain films were negative and were of no help whatever in the subsequent diagnosis. In one case (Fig. 2) the lesion was partially calcified and ossified and was clearly visible within the spinal canal just posterior to the body of the seventh cervical vertebra.

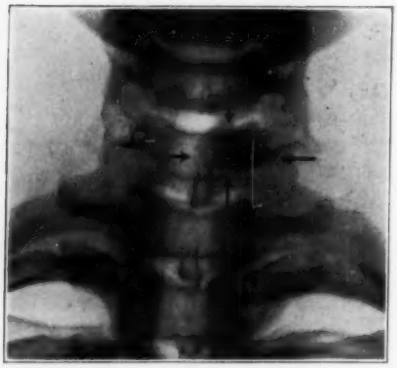

FIG. 2

Overlying the body of the seventh cervical vertebra there is an irregular shadow of increased density produced by calcium and bone within a protrusion of the seventh cervical disc.

Narrowed Intervertebral-Joint Space

The question is often raised as to the relation of a narrowed intervertebral-joint space to intraspinal protrusion of the associated disc. In this regard we have always stated that such a finding was of little significance, because narrowing of the intervertebral space at the site of a protruded disc occurred consistently in only a small percentage of cases. Such a finding may also result from degeneration and fibrosis of an intervertebral disc without protrusion, and many patients in whom such a change is observed are free from any symptoms that could be attributed to a lesion at that level. The data concerning the presence of narrowed intervertebral discs in this series of cases are worthy of comment. In twenty-seven cases a narrowed intervertebral-joint space was observed at one or another point in the spinal column. In nineteen instances the narrowed disc or discs were at a different level than the site of the lesions found at operation. In sixteen instances the level of the narrowed intervertebral-joint space coincided with the site of the lesion which was removed by the surgeon. While this would appear at first to be significant, the presence of multiple, narrowed intervertebral-joint spaces in ten of these sixteen cases makes the occurrence of a protruded disc at one segment of little relative importance.

The fourth and fifth lumbar intervertebral-joint spaces were most frequently narrowed and there were fifteen instances of each. In the group of cases with a narrowed fourth lumbar joint space, a corresponding surgical lesion was found in six instances. In fifteen cases of a narrowed fifth lumbar intervertebral-joint space a corresponding surgical lesion was demonstrated in nine. While this suggests that a narrowed fourth or fifth lumbar intervertebral-joint space is of some importance, the complete data indicate that there is no dependable and consistent relationship between a narrowed intervertebral-joint space and the presence of a protruded disc at the same level.

Hypertrophic Changes

In seventeen of the fifty cases there was evidence of hypertrophic changes about the margins of one or more intervertebral-joint spaces. In only five cases, however, were the hypertrophic changes localized about the margins of the intervertebral joint at the site of the lesion. It is quite evident, therefore, that the presence of proliferative changes in bone is of no help in the direct localization of protruded intervertebral discs.

Compression Fractures

In this series, a compression fracture of one or more vertebral bodies was rare. Such a combination occurred in only three cases, and in two of these cases the protruded disc was quite remote from the level of the compression fracture. In the third case a protruded disc was removed from the eleventh thoracic intervertebral space and an old compression fracture of the bodies of the twelfth thoracic and the first lumbar vertebrae was present. This group is probably too small to establish a dependable relationship between fracture and disc protrusion.

Examination with Lipiodol

In fourteen cases a study of the spinal subarachnoid space by means of lipiodol was not carried out; nine of these patients were operated on prior to 1930 and five in subsequent years. The neurological examination in each case so clearly established the level of the lesion that operation was carried out directly with the expectation of finding a tumor affecting the spinal cord. This experience indicates that the use of lipiodol is not always necessary to localize the level of a lesion, especially when it is above the conus medullaris. The use of lipiodol, however, is necessary whenever it is desirable to establish with reasonable certainty preoperatively whether the lesion is a protruded disc, a tumor, or inflammatory disease. This is particularly true in the case of lesions below the conus medullaris wherein the clinical localization of compression to individual nerve roots is extremely difficult. The use of lipiodol indiscriminately in all cases of persistent low-back or sciatic pain is not to be recommended. As stated elsewhere in this paper, certain criteria that may be determined from a carefully taken history and physical examination, and more significantly

from the results of examination of the spinal fluid and epidural injection, should be present before a study with lipiodol is considered. The use of lipiodol is always associated with a certain degree of risk, for we recognize that it has certain irritant properties in the subarachnoid space. However, in the properly selected case, we feel that the information to be derived from its use far outweighs any disadvantages that it may have. Its use in the case of recognized inflammatory disease is not recommended.

The procedure that we employ for the roentgenographic identification of protruded intervertebral discs by means of lipiodol is the same that we have used for several years for the localization of tumors involving the spinal cord. In the past, one of us [7] has emphasized the necessity of using sufficient radiopaque oil (five cubic centimeters) to fill the subarachnoid space at any desired level, in order to visualize small non-obstructing tumors which can be identified by a filling defect; this defect assumes a characteristic shape depending on whether the lesion is extradural, intradural, or intramedullary. Since the majority of protruded intervertebral discs produce no obstruction and occur in a region where the spinal canal is relatively large, it is hopeless to attempt to visualize or to locate them by means of one or two cubic centimeters of radiopaque oil, which can easily trickle past the lesion without any significant changes in contour.

Technique

The lumbar injection is preferred. After injection, the patient is placed in a sitting position on the fluoroscopic table for about one minute in order to permit all of the oil to gravitate to the sacral cul-de-sac. This being done, the patient is placed in the prone position on a tilting fluoroscopic table with the foot end of the table depressed to prevent cephalad excursion of the oil until the actual fluoroscopic observation is started. The shoulders are supported by padded shoulder rests. If the oil is seen to be low down in the lumbar canal, the foot of the tilting table is gradually elevated and the shadow of the oil as it moves cephalad is carefully observed (Fig. 3).

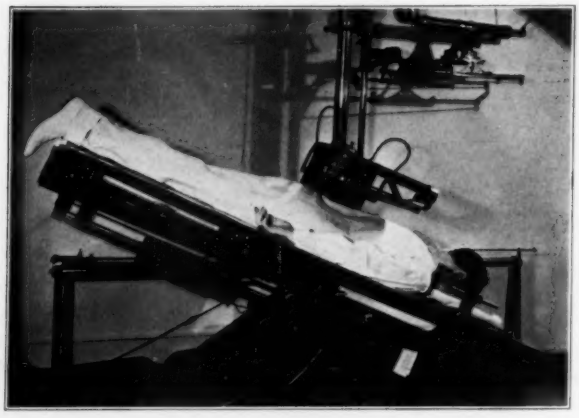

FIG. 3

Tilting fluoroscopic table, showing one phase of the examination during the cephalad excursion of the lipiodol. Note the padded shoulder rests that support the patient.

When the pupils are properly dilated, it is easy to recognize

the intervertebral-joint spaces and to observe their relation to any defects that may appear. If the symptoms indicate that the lesion involves the lumbar roots, it may not be necessary to observe the movement of the oil much above the conus medullaris. However, we routinely follow the oil to the cervical region in all cases in an effort to pick up multiple associated or unsuspected lesions. Since protruding discs are situated in the anterior portion of the spinal canal, they produce their maximal filling defect when the patient is lying prone. In this position the heavy oil will gravitate to the ventral aspect of the subarachnoid space and is in close contact with the protruding disc. If a persistent defect is observed, films should be made as quickly as possible without disturbing the position of the patient. The most satisfactory results are obtained when a film is substituted for the fluoroscopic screen and the exposure made with the tube beneath the table. The modern "spot-film" devices for fluoroscopy and roentgenography of the stomach are ideal for this work since they permit a rapid change from fluoroscopy to roentgenography. This is extremely important, for if one wishes to record on films the appearance of the fluoroscopic image, which to our minds is the most significant part of the examination, it is necessary to have some means of roentgenographing the lipiodol "on the move".

Whether or not a defect is observed, fluoroscopic examination should include observations in the prone-oblique and lateral positions. Only by this means is it possible to determine accurately the anterior or anterolateral position of a mass that indents the column of lipiodol. After the excursion of lipiodol has been studied in the foregoing positions, we routinely have the patient sit up again for one minute in order to collect the oil in the sacral cul-de-sac, and then repeat the examination with the patient supine. Many protruded discs will not produce a recognizable deformity when the patient is supine; nevertheless, we feel that this part of the examination is necessary in order to determine confidently whether or not a tumor of the spinal cord is present. The presence of a tumor of the spinal cord in addition to a prolapsed disc is not improbable and two such cases have been reported by one of us [6].

Defects in the Column of Lipiodol *

Because the protruded fragment of the disc is extradural, it will push against the column of lipiodol in the subarachnoid space, on the ventral or ventrolateral aspect, and indent it or displace it posteriorly and sometimes laterally. Complete obstruction of the column of lipiodol has been observed in the case of large protrusions. The classic filling defect is a sharply defined, rounded indentation in the lipiodol shadow on one side of the midline opposite an intervertebral disc (Fig. 4, *a* and *b*). The extent

* The discrepancy between the figures given in this section and those given in the surgical section results from the fact that the surgical data include fourteen cases in which examinations with lipiodol were not made, two cases with double lesions in which the obstruction produced by one lesion prevented the second lesion from being seen, and one case in which the examination with lipiodol was negative.

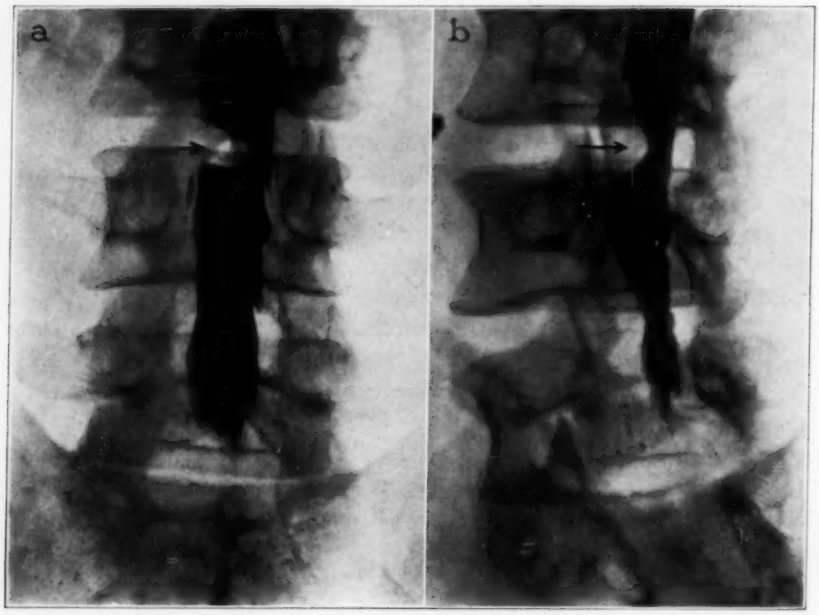

FIG. 4

Characteristic defect in the column of lipiodol produced by a protrusion of the third lumbar intervertebral disc: *a*, prone position; *b*, prone-oblique position.

of this defect is influenced naturally by the size of the protrusion. It is generally better defined in a prone-oblique position, and may or may not be evident in the lateral view.

In twenty-two cases the defect was unilateral,—on the right side in ten and on the left in twelve. The defect was bilateral in twelve cases. In six cases multiple defects were observed (Fig. 5, *a* and *b*). In one case the lateral view was the only position that revealed the defect, and in the remaining case examination with lipiodol was reported as negative. No obstruction to the flow of the lipiodol was evident in twenty-nine cases. There were four cases of partial obstruction and three of complete obstruction. In two of the latter cases the complete obstruction prevented the visualization of a second lesion of the adjoining disc (Fig. 6, *a* and *b*).

In addition to the outline of the defect produced by the mass of the protruded disc, significant changes in the shadows of the nerve roots may be present at the level of the lesion. These consist of oedema of one or more nerve roots, which may be recognized by a broadening of the negative shadow of the nerve root if it is outlined (Fig. 7), and by displacement or deformity of the shadows of nerve roots within the subarachnoid space. If the oil has extended into the extradural portion of the nerve sheath, displacement or deformity of this root may occasionally be visible. In a few cases the shadow of the oil in the extradural portion of a nerve sheath was terminated sharply at the level of the protruded disc, suggesting pressure at this point. In some instances in which several nerve sheaths were

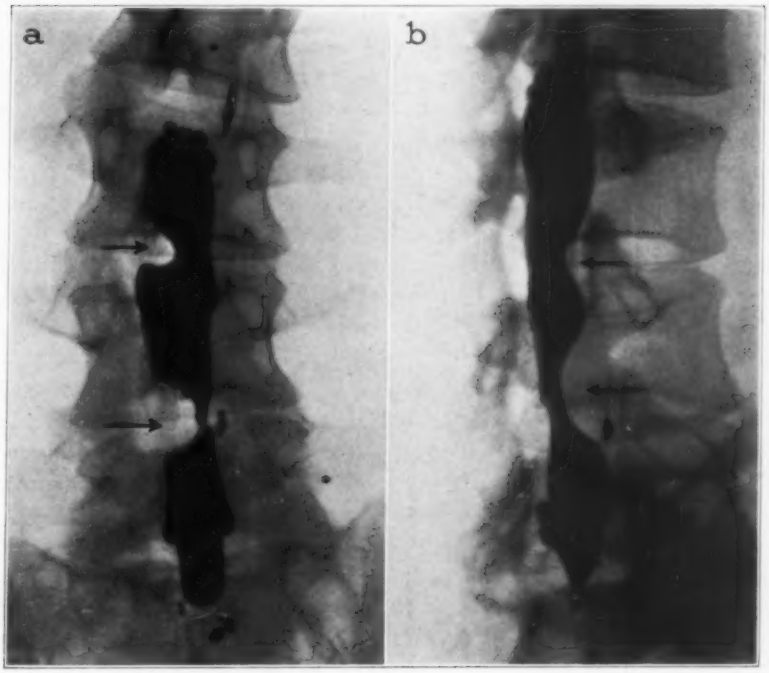

FIG. 5

Multiple defects in column of lipiodol produced by a protrusion to the left of the third and fourth lumbar intervertebral discs: *a*, prone position; *b*, prone-oblique position.

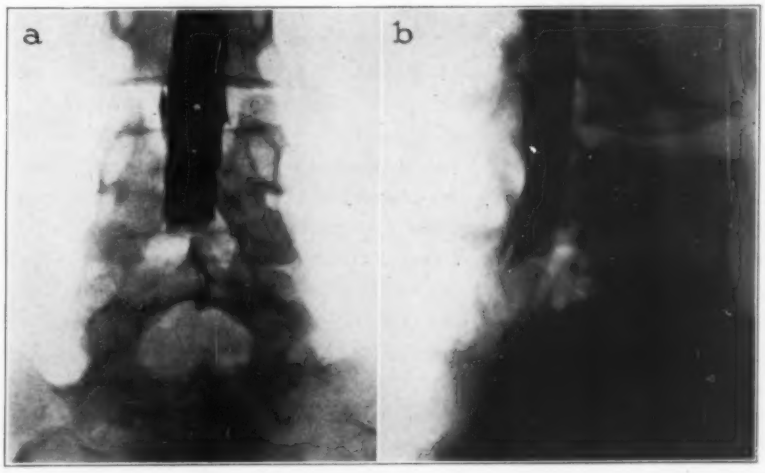

FIG. 6

Complete obstruction of the column of lipiodol produced by a large protrusion of the fourth lumbar intervertebral disc. Because of the complete obstruction, a second protrusion, involving the fifth lumbar intervertebral disc, could not be visualized: *a*, prone position; *b*, lateral position, revealing posterior displacement of the lipiodol shadow at point of obstruction.

visible, it was noticed that there was persistent non-filling of the sheaths on the side of the lesion; this is probably of significance and suggests pressure or oedema of the nerve. However, nerve sheaths fill so inconsistently that lack of filling on one side cannot be depended upon as a reliable sign of protrusion of the disc.

The distribution of defects revealed by studies with lipiodol in this series was as follows: tenth thoracic, one; eleventh thoracic, two; twelfth thoracic, one; first lumbar, one; second lumbar, one; third lumbar, eight; fourth lumbar, fifteen; and fifth lumbar, fourteen. There were six cases of multiple protrusions, which were distributed as follows: third and fourth lumbar, three; fourth and fifth lumbar, one; third and fifth lumbar, one; and one case in which all the discs between the eleventh thoracic and the fifth lumbar vertebrae were involved.

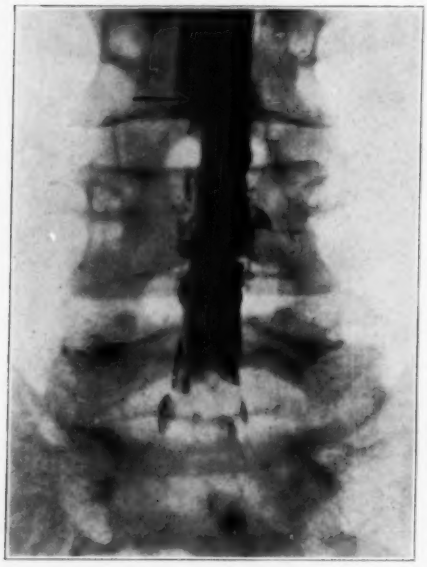

FIG. 7

Compression of lipiodol by a protruded third lumbar intervertebral disc. The arrow indicates an oedematous fourth lumbar root medial to which the fifth lumbar root may be seen.

Examination of the region of the lumbosacral joint requires in most cases an additional manoeuver, because there is not available in the United States any tilting fluoroscopic table that will permit both ends of the table to be raised to a vertical or nearly vertical position, which is necessary in order to move the lipiodol into the sacral cul-de-sac and also into the upper portion of the spinal canal when the patient is in the prone position. When the patient is in this position, the sacrum curves upward and the lipiodol will not move across the lumbosacral junction dorsally into the sacral cul-de-sac unless the foot end of the table can be tipped down to an angle of at least 45 degrees. Since the maximal downward tilt of one end of most fluoroscopic tables is limited to about 20 degrees, it is necessary to reverse the position of the patient on the table in order to obtain a tilt great enough to fill the sacral cul-de-sac. In our routine investigations with lipiodol for protruded discs this is the concluding step of the examination. After the areas above the lumbosacral joint have been examined, the table is brought back to a horizontal position and the patient is allowed to sit up long enough to substitute a foot rest for the shoulder rest. He is then placed prone on the table again with his head at the end formerly occupied by his feet. The head end of the table is then elevated as much as necessary to produce filling of the sacral cul-de-sac. Because of the gradual fusiform narrowing

of the terminal portion of the subarachnoid space and the proportionately larger spinal canal at the fifth lumbar vertebra, protruded discs at the lumbosacral junction will not produce as marked filling defects as they would at higher levels. Since it is desirable to fill the sacral cul-de-sac as completely as possible in order to visualize the maximal effect of any protrusion, it may be necessary to raise the patient to almost a standing position.

Hampton and Robinson's recent work [10] has placed the lipiodol findings in cases of protruded discs on a definite anatomical and pathological basis, a knowledge of which is fundamental to a successful and conclusive examination. They call attention to the fact that the fifth lumbar root and most of the first sacral root are extradural at the lumbosacral junction, and, therefore, are outside the confines of the lipiodol in the subarachnoid space unless it has followed along their nerve sheaths. For this reason, a lesion compressing either of these roots may produce a minimal defect in the contiguous subarachnoid space. Examiners and neurosurgeons should, therefore, not be surprised when the size of the protruded fragment removed at the lumbosacral junction is not in keeping with the extent of the defect in the column of lipiodol.

DIFFERENTIAL DIAGNOSIS

In the differential diagnosis of protrusion of an intervertebral disc there are many conditions to be considered. Chief among these is intraspinal neoplasm, but since the treatment is the same for the two conditions—namely, laminectomy and removal—this should not concern us unduly. In fact, a protruded disc is just as much a tumor of the spinal cord as is an endothelioma arising from the spinal meninges, and a protruded disc can produce paralysis and sphincteric disturbances, with resulting infection in the urinary tract and death, just as well as can a primary neoplasm. It is, of course, true that a protruded disc is not a neoplasm, for it does not grow in the sense of neoplasia, but it does tend to increase in size and, in time, just as much damage may be done to the spinal cord and its nerves as by a true neoplasm.

The conditions which most closely resemble protrusion of the intervertebral disc are: low-back pain (whatever its cause), lumbosacral strain, sacro-iliac disease, spondylitis, and hypertrophic changes involving the spine. Likewise, brachial-plexus or lumbosacral-plexus neuritis may be the diagnosis in a given case until examination of the spinal fluid reveals an increased total protein, and fluoroscopic study with lipiodol then discloses the real cause of the painful condition. Usually there is a paucity of neurological findings in cases of protrusion of the discs, but in some cases there is definite and well-marked evidence of disease of the spinal cord. In some of these cases the clinical picture may be that of syringomyelia or multiple sclerosis. In one of our cases at the Clinic, because of an associated severe diabetes mellitus, the diagnosis of diabetic neuritis was entertained until fluoroscopic study with lipiodol settled the question.

Sciatic neuritis and fibrositis have likewise given trouble in cases in which the condition finally proved to be due to a protruded intervertebral disc.

It is not within the scope of this paper to go into the diagnosis of each of these conditions. It is suggested only that, when a patient has received the usual recognized conservative treatment for the condition from which he is considered to be suffering, without appreciable benefit, the possibility of a protruded disc be considered as the cause of his disability. This condition should always be considered in cases of intractable and recurrent "sciatica".

TREATMENT

Protruded discs that are not causing compression on nerve roots or spinal cord probably do not require any treatment, at least it is not our policy at the present time at the Clinic to advise laminectomy unless the defect in the column of lipiodol opposite the disc corresponds to the neurological level of clinical symptoms. For instance, in the course of fluoroscopic study of the column of lipiodol in the spinal canal, we have found defects classic for a protruded disc, but we have not advised laminectomy because the defect was in the lumbar region and the patient had symptoms and signs indicative of a lesion involving the thoracic portion of the spinal cord.

When the defect is at such a level that a mass at that level could produce the symptoms and signs elicited by the history and on neurological examination, laminectomy for removal of the protruded portion of the disc is advised. Laminectomy in such cases is just as necessary as laminectomy for removal of an intraspinal neurofibroma or meningioma. Decompressive laminectomy is not sufficient. The protruded fibrocartilaginous mass must be removed if the patient is to receive the optimal amount of relief from his symptoms.

The anaesthetic of choice is ether and this is best administered by the open drop method over the end of a Magill intratracheal tube which has been introduced after the patient has been anaesthetized by nitrous oxide and oxygen. The patient is then placed on the operating table as for any laminectomy. We at the Clinic prefer to perform cervical laminectomies with the patient in the upright position [3]; other laminectomies are performed with the patient prone, the torso being supported by two rolled pillows, so that there is no interference with breathing. When the lesion is low in the lumbar region or at the lumbosacral space, a large, soft, flat pillow is placed across the lower ends of the rolled pillows and between the symphysis pubis and the xiphoid process in order to increase the prominence of the lumbar spinous processes. This facilitates exposure in the lumbar region where the muscles are quite large and the distance from the skin to the anterior surface of the dura mater (or disc) is greater than that at any other level of the spine.

Subperiosteal resection of the spinous processes and laminae of the two vertebrae between which the protrusion has occurred is sufficient for

adequate exposure and removal of the disc. Occasionally laminectomy is necessarily more extensive, and often only a portion of the laminae of one of the vertebrae needs to be removed. If protrusion has occurred in the midline in the lumbar or lumbosacral region, laminectomy does not have to be wide; however, if the protrusion is lateral, as it frequently is, it may be necessary to remove the articulating facets on that side in order to secure adequate exposure, thorough removal of the protruded disc, and thereby adequate decompression of the involved nerve root. Whenever possible, laminectomy should be narrow and the facets should be preserved. This maintains normal stability of the spinal column following operation. In the cervical and thoracic regions, wide laminectomy, at least on one side, is the rule, for here the spinal cord must be rotated in order to obtain satisfactory exposure. Section of one or more teeth of the dentate ligament facilitates rotation of the cord.

Unilateral protrusions in the cervical region can be removed by hemilaminectomy. This procedure is always preferable when one is dealing with intraspinal lesions in the cervical region, because the neck is left in a more nearly normal condition after operation, and, in spite of the free motion of the cervical spine, there is little or no danger of its dislocation,—a condition which does occur, although rarely, following bilateral cervical laminectomy [2].

The protruded disc may be removed extradurally or transdurally. We at the Clinic have no set rule in regard to this, for the operation should be adapted to the particular case after laminectomy has been performed. If the protrusion has occurred to one side, extradural removal is the procedure of choice and it can be accomplished without difficulty. If the protrusion is in the midline, and particularly if the extruded mass is small, transdural removal is easier and is accompanied by less bleeding. If the dura is retracted for an anterior extradural approach to a small herniation of the disc, bleeding from the extradural vessels is likely to be sharp and very troublesome. In the case of larger lesions either approach may be used without encountering much bleeding. It is our feeling that the extradural veins are either thrombosed or sufficiently displaced by the larger protrusions, so that they are not injured during the removal of the mass, and, consequently, hemorrhage is less. The consistency of the protrusions varies considerably,—some are bony and hard, others are soft and fluctuant. The fluctuant masses should be aspirated with a small needle to exclude the possibility of pus in a tuberculous lesion before the mass is incised, for to incise such a lesion in the presence of an open dura mater is fatal.

From the point of view of surgical anatomy, protrusions are of two kinds: (1) those that pop out (Fig. 1) when the dura mater is retracted and the thinned-out posterior longitudinal ligament is incised, and (2) those that are firmly adherent to the adjacent vertebrae and require sharp dissection for their removal. The former at times pop out and need only to be picked up with forceps when the overlying dura mater is retracted,

the posterior longitudinal ligament overlying the disc having been completely destroyed. Destruction of the ligament might be the cause or the result of protrusion of the disc; it is our feeling, however, that it is the result rather than the cause, for many protruded discs are seen that are still partly held in place by the intact ligament. Incision of the ligament in such cases allows the protruded disc to become much more prominent, and after incision, with release of the restraining force exerted by the ligament, the nucleus pulposus and a portion of the annulus fibrosus may be found lying free posterior to the ligament and anterior to the dura mater.

All protruded tissue that is causing or could cause pressure on the nerve roots or spinal cord should be removed. When removal has been completed, the anterior and lateral surfaces of the spinal canal should be smooth and there should be no encroachment upon the canal.

In spite of meticulous care in the performance of laminectomy and the removal of the protruded disc, drainage usually is necessary for a period of from twenty-four to forty-eight hours. Rarely a wound is closed tightly without a drain. Often a Penrose cigarette drain, left in just above the level of the dura mater for twenty-four hours, is sufficient; however, it is frequently necessary to use one or more strips of plain gauze packing, one inch in width, between the dura mater and the site where the disc was removed. The disc itself is avascular, but the surrounding extradural structures are very prone to ooze.

Patients are kept in bed for from twelve to fourteen days following operation, during which time they rest on soft pillows so arranged as to keep the spine straight. They are turned every four hours. The skin sutures (silk or dermal) are removed on the tenth postoperative day. Catheterization is performed every eight hours if the patient is unable to void. If voluntary urination does not occur by the third day, an inlying urethral catheter is placed for continuous drainage of the bladder until the patient is out of bed. The inlying catheter and the bladder are irrigated twice daily with a 4-per cent. solution of boric acid, and seven and one-half grains (0.48 grams) of methenamine and fifteen grains (1.0 gram) of ammonium chloride are given by mouth three times daily. In our experience this is the best way to avoid cystitis and infections of the urinary tract. The catheter is removed after five days and is replaced by another sterile catheter. Of course, all catheterizations are done under as nearly aseptic conditions as possible. Patients are allowed to sit on the edge of the bed on the twelfth or fourteenth day and in a chair the next day, and they are permitted to walk the following day. After being up in the hospital for a few days they report to the office for postoperative examination, and they are allowed to leave town for their homes by the end of the third week following operation. They are advised to refrain from heavy lifting and straining for a period of three months, after which time they are encouraged to return gradually to their former activities. No braces or special supports are advised.

ANALYSIS OF CASES

As has been stated, this study consists of a careful analysis of the records of fifty consecutive patients who were operated on at The Mayo Clinic by members of the neurosurgical staff, prior to November 1, 1936, for the protrusion of one or more intervertebral discs. In each case the diagnosis was verified at the time of laminectomy. Cases in which a diagnosis of a protruded disc was made, but in which, for one reason or another, laminectomy for removal of the protruded disc was not performed, are not included in this series. Likewise cases of extradural chondroma or chordoma are not included.

Although any intervertebral disc may protrude into the spinal canal, with the subsequent production of compression on the spinal cord or nerve roots, the discs in the lumbar region are most commonly involved. In our fifty cases there were forty-two instances of protrusion of the lumbar discs (thirty-eight patients) as against seven protruding thoracic discs and only five cervical discs. Multiple protrusions were found five times in the lumbar region, and once in the thoracic region. Not only are protrusions found most often in the lumbar region, but certain discs seem to be more vulnerable than others. For instance, the fifth lumbar or lumbosacral disc was protruded in twenty cases, the fourth lumbar in sixteen, the third in five, and the first and second each in one case. In the thoracic region, the fifth, sixth, and eleventh discs were found to be protruded in two cases each, whereas in the seventh case involvement was of the tenth thoracic disc. In the cervical region, the fifth and seventh discs were each found to be protruded in two cases. In a fifth case, protrusion occurred at the sixth disc.

Pain is the chief complaint in cases of protrusion of the discs and it may well be the only one. It was the chief symptom in forty-five of the fifty cases, there being only five patients who did not complain of pain. The next most important point to determine in taking the history is whether the patient has had an injury to the spine (excluding vertebral fracture, for the disc is rarely protruded in cases of fracture of the vertebra) or whether he has subjected the back to any unusual stress or strain. In thirty-seven of the cases there was a history of trauma to the spine. Trauma may be followed immediately by pain in the back and down one or more extremity, or pain and disability may occur after an interval of weeks or months.

The condition occurs most frequently in males, as one would naturally expect, since it is the male who more often subjects his back to unusual stresses and strains and is often employed where accidental injury is liable to occur. That thirty-nine of the patients in this series were males is confirmatory of this statement.

Apparently, protrusion of an intervertebral disc may occur at any age, although, as is to be expected, it is seen most often in the third, fourth, and fifth decades of life. The youngest patient in this series was sixteen years old (and she had had symptoms for five months prior to operation)

and the oldest patient was seventy-three. The average age for the group was thirty-nine and eight-tenths years.

Ordinarily the symptoms for which the patient seeks relief have been present for a long time when he finally comes to operation for removal of a protruded disc. All of the usual conservative methods of treatment for lumbago, low-back pain, sacro-iliac strain, lumbosacral pain, sciatica, arthritis, and neuritis ordinarily have been tried before an accurate diagnosis is made and the proper curative treatment is instituted.

Those patients who have protrusions of the discs in the cervical and thoracic regions come to operation sooner than those whose lesions are in the lumbar region. This is explained, we believe, on anatomical grounds, for, in the cervical and the thoracic regions, the spinal cord occupies most of the spinal canal and a small intraspinal tumefaction will cause compression and neurological signs relatively early; whereas, in the lumbar region, the dural envelope can be encroached upon to a considerable degree before symptoms and signs other than those of root pain are produced. In our series of cases the average duration of symptoms before removal of the offending protruded disc was one and four-tenths years (shortest, one month; longest, three years) for the cervical group; two and four-tenths years (shortest, one month; longest, seven years) for the thoracic group, and, for the lumbar group, four and eight-tenths years (shortest, one month; longest, twenty-four years).

Of the forty-five patients with pain, twenty-six complained of low-back pain and pain along the course of one or both sciatic nerves; eleven patients gave a history of sciatic pain only; and four patients reported low-back pain without sciatic projection. The other four patients referred the pain to the neck, the upper extremities, or the upper portion of the spine. Of these forty-five patients, the pain was unilateral in thirty and bilateral in fifteen. Thirty-seven patients suffered from pain along the course of the sciatic nerve or its branches. Persistent, intractable, sciatic pain should, therefore, arouse suspicion as to the possibility of a protruded lumbar intervertebral disc as the underlying cause.

Neurological examination should be carried out in each case, and care should be exercised to detect slight deviations from the normal, as marked neurological changes are rarely found. Often diminution of an Achilles-tendon reflex, associated with a positive Lasègue sign on the same side, will constitute the sole neurological finding. The projection of the pain as described by the patient should be noted carefully, and, even though a protruded disc is found later, operative removal of the disc, with the promise of relief, should not be advised unless the abnormal disc corresponds to the level of root pain.

Although the neurological findings were usually slight, some variation from the normal was noted in forty of the fifty cases analyzed. Often the sole finding was a diminished or absent Achilles-tendon reflex on the side of the pain. In fifteen cases a diagnosis of compression of the cord or cauda equina, with the level of compression, was made on the basis of the

neurological findings, and fourteen of these fifteen patients were operated on without the use of intraspinal lipiodol. A protruded disc, which was causing the compression and symptoms, was identified in each case.

Lumbar puncture to determine the hydrodynamics of the cerebrospinal fluid, and for the purpose of obtaining a specimen of fluid for chemical and microscopic examination, is indicated in all cases of persistent pain which partakes of the nature of radicular involvement. Queckenstedt's test should be performed routinely to determine the presence or absence of subarachnoid block above the level of the spinal-puncture needle. In cases of a protruded disc, this sign is negative most of the time, but, when positive, it is of the utmost importance. This test is much more frequently positive in cases of intraspinal neoplasm. In this series only four patients were found on lumbar puncture to have subarachnoid block. One of these patients had an intraspinal meningioma which was producing the block, and the meningioma lay above the protruded disc which was causing root pain. One patient had a large protrusion of the first lumbar disc. The other two patients had a definite sensory level on neurological examination and, at operation, the protrusion of the fifth cervical disc in one case and of the sixth cervical disc in the other was found to be of sufficient size to cause complete block of the cervical canal. No doubt more instances of subarachnoid block would be found in cases of protrusion of vertebral discs if the subarachnoid space were punctured below the lesion; however, owing to the fact that these protrusions occur most often low in the lumbar region, the needle most frequently is above the lesion, and, consequently, no block could be expected.

The cerebrospinal fluid is examined for evidence of syphilis; a cell count and determination of the total protein are made; the fluid is examined for the presence of globulin; and a colloidal curve is charted. The most important test is the determination of the total protein. It was thought for a time that a total-protein reading greater than forty milligrams per 100 cubic centimeters was essential before a diagnosis of a protruded disc could be considered. However, it has been learned that this is not true. Spinal fluid was obtained for examination in forty-nine of the fifty cases, but no report of the total-protein content was made for one reason or another in eight of these. Most of these cases were seen early and before routine determinations of total protein of the cerebrospinal fluid were being made. The highest value for total protein was 360 milligrams; the lowest, twenty milligrams per 100 cubic centimeters of fluid. We have arbitrarily set forty milligrams of total protein per 100 cubic centimeters of fluid as high normal. In this group of forty-one cases in which the total protein was estimated, there were thirty cases in which the total protein was greater than forty milligrams per 100 cubic centimeters of fluid. Thus, there were eleven patients, found to have protruded intervertebral discs that were causing symptoms, in whom the protein content of the cerebrospinal fluid was normal. Again, we would like to

emphasize the point that in the majority of cases the fluid sent to the laboratory for examination is obtained above the level of the protruded disc.

Because of this fact, we have come to lay considerable stress on the value of a procedure which we term the "reverse" Queckenstedt test [13]. With a spinal-puncture needle in the lumbar canal, 1-per-cent. procaine hydrochloride is injected into the caudal epidural space. This procedure has not been done routinely, and it was performed in only twelve cases in this series. In seven of these twelve cases, there was a positive reaction, which definitely suggested the presence of a lesion involving the cauda equina. When a solution is injected extradurally into the sacral hiatus, the dura mater is compressed and, if there is a lesion that is already compressing one or more roots of the cauda equina, unbearable pain in the distribution of the involved root will follow as further encroachment on that root is produced. Ordinarily, as the solution is injected extradurally, there is a rise in intraspinal pressure, as determined by the manometer attached to the spinal-puncture needle in the lumbar region. If a low-lying caudal lesion of sufficient size to obliterate the caudal sac is present, no increase in the manometric reading will be observed.

Unless a definite level of motor or sensory loss is determined on neurological examination, subarachnoid injection of a radiopaque oil for fluoroscopic and roentgenographic examination of the spinal canal is essential to establish the diagnosis of an intraspinal lesion. Lipiodol in experienced hands not only enables the making of the diagnosis of intraspinal lesion, but, in the majority of cases, it is also possible to state that the lesion is a protrusion of a certain intervertebral disc. Intraspinal lipiodol was employed in thirty-six of the fifty cases. If such a study is negative for an intraspinal lesion, laminectomy for removal of a protruded disc should not be considered, for, in experienced hands, the smallest of defects can be diagnosed and localized by this technique.

When the diagnosis of protrusion of an intervertebral disc has been made, and if the protruded disc is at a level that could account for the patient's symptoms, the treatment is laminectomy and removal of the protruded portion of the disc. Rarely, it may be necessary to conclude the operation after laminectomy has been performed and the protruded disc has been identified, but the results of a decompressive operation alone militate against this procedure as a method of treatment. In six of the present series of fifty cases the disc was not removed. Two of these patients showed no improvement; two gave evidence of slight improvement; and only two were completely relieved.

ILLUSTRATIVE CASES

CASE 1. The patient, a professional man, thirty-four years of age, came to the Clinic because of pain in the lumbar region with projection down both sciatic nerves. This pain had troubled him for one year and it was aggravated by walking. There was no history of injury. On examination, the lumbosacral spine was found to be rigid.

Lasègue's sign was positive on both sides. The Achilles-tendon reflexes were normal and there was no motor or sensory disturbance. Roentgenograms of the lumbosacral spine were negative.

When an attempt was made to obtain a specimen of fluid from the spinal canal through the fourth lumbar interspace, the procedure caused excruciating pain and the needle was then inserted in the third interspace without incident. The fluid gave a negative Wassermann reaction. The globulin test likewise was negative. The total-protein content was not determined.

Because of the intractable bilateral sciatic pain and the inability to obtain fluid through the fourth lumbar interspace, a diagnosis of tumor of the spinal cord (cauda equina) was made. On January 14, 1922, Dr. Adson performed a laminectomy and removed a protrusion of the fourth lumbar intervertebral disc (Fig. 8). The patient's convalescence was uneventful; he has been free from the sciatic pain since and has been in his office daily.

This patient was seen before routine determinations of the total protein of the spinal fluid were being made, and, therefore, we have no knowledge of this factor which might have been of great value in the diagnosis of this case. Likewise, today, this patient undoubtedly would have been subjected to study with lipiodol preliminary to laminectomy, for neurological examination in this case was negative for localizing signs. This is the first proved case of protruded intervertebral disc in which operation was performed at the Clinic.

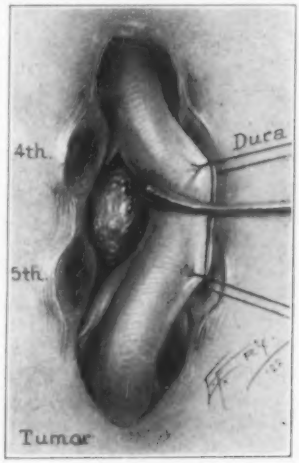

FIG. 8

Protruded fourth lumbar intervertebral disc producing bilateral sciatic pain. Removal of this protrusion resulted in complete relief from symptoms. (*Courtesy of Archives of Neurology and Psychiatry.*[4])

CASE 2. A man, thirty-five years old, came to the Clinic on November 4, 1935, because of pain in the left shoulder and left upper arm. He said that he had been in an automobile accident in 1932, at which time he had suffered dislocation of the left shoulder. For eleven months prior to registration he had experienced at first intermittent, and later constant, pain in the left shoulder with projection of pain along the upper extremity to the finger tips. Coughing, sneezing, and straining at stool aggravated the pain.

On examination, the patient was found to be well developed and well nourished. The neck motions were guarded. When the head and neck were inclined to the right or backward, the pain in the left upper extremity was increased. The muscles of his left upper extremity were slightly smaller than those of the right. The patient was right-handed and he had not considered the difference of significance. The deep reflexes in the left upper extremity were definitely increased over those of the opposite member. Sensation was normal. Numerous roentgenograms of the cervical spinal column, including stereoscopic views, were negative. On lumbar puncture, there was no subarachnoid block. The fluid was clear and contained seventy milligrams of total protein per 100 cubic centimeters, and the globulin test was positive.

Five cubic centimeters of lipiodol was then injected into the lumbar subarachnoid space for fluoroscopic study and the patient was examined on the tilting table. A partially obstructing lesion was demonstrated in the lower cervical region. Laminectomy was performed on November 14, 1935, at which time a protrusion of the disc between the seventh cervical and the first thoracic vertebrae was removed. This protrusion had

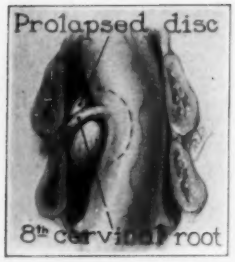

FIG. 9

Protrusion of seventh cervical intervertebral disc, showing stretching of nerve root and distortion of spinal cord.

occurred on the left side and the eighth cervical nerve was stretched over the cartilaginous protrusion (Fig. 9). The patient's convalescence was uneventful; he has remained free from pain and is back at his usual work.

This patient suffered intractable unilateral root pain. There was a history of injury, and the total protein was elevated. Lipiodol studies enabled us to make a diagnosis of intraspinal lesion and thus indicated the proper treatment, which was curative.

CASE 3. This patient, a white man of thirty-three years, registered at the Clinic on September 2, 1936, seeking relief from a chronic pain that was present in his back and which was projected down along the course of the right sciatic nerve. He stated that he had sprained his back four years before while lifting one end of an automobile. He had become so weak that he could not stand on his feet, and he had had recurrent attacks of pain ever since. Six months prior to registration he had begun to experience severe pain in the distribution of the right sciatic nerve. This pain was made worse by coughing, sneezing, and straining. The usual conservative treatment for low-back pain and sciatica had afforded little or no relief.

On examination at the Clinic, there was marked tenderness over the lower lumbar spine and over the right sacro-iliac joint. There was muscle wasting of the right thigh and leg. Lasègue's sign was positive on the right. The right Achilles-tendon reflex was diminished 50 per cent., whereas the left Achilles-tendon reflex was normal. Roentgenograms disclosed narrowing of the lumbosacral joint. On lumbar puncture, clear fluid, without subarachnoid block, was obtained. The total protein was seventy-five milligrams per 100 cubic centimeters and the globulin test was positive. On fluoroscopic study of the spinal canal with lipiodol, a persistent extradural defect opposite the lumbosacral disc on the right was detected (Fig. 10).

On September 9, 1936, laminectomy, consisting of the removal of the spines and a portion of the laminae of the fifth lumbar and first sacral vertebrae, was performed. A large extradural mass was found compressing the right fifth lumbar root. The nerve root was much enlarged as a result of oedema from compression. This mass, a protruded disc, was removed (Fig. 11). Convalescence was uneventful and the patient has been free from pain ever since.

FIG. 10

Filling defect produced by a protrusion in the right anterolateral portion of the column of lipiodol opposite the fifth lumbar disc.

This case might be called a classic example of protrusion of a lumbar intervertebral disc,—that is, there was a history of injury or sprain involving the lower part of the back. Subsequently the pain had become more severe, and there was projection in one sciatic nerve. Examination of the spinal fluid disclosed an increased amount of total

protein, and fluoroscopic studies with lipiodol made possible a positive diagnosis of protrusion of the lumbosacral disc to the right side. The original roentgenograms disclosed narrowing of the lumbosacral disc, but this finding alone was not sufficient justification for assuming that the disc protruded into the spinal canal, for roentgenograms most often do not show any narrowing in cases of protrusion.

CASE 4. This patient, a woman twenty-eight years of age, was referred to the Clinic by her local physician because of intractable left sciatic pain of one year's duration. During the second stage of a difficult labor, she had complained of pain low in the back and shooting up the spine. One month postpartum, pain in the distribution of the left sciatic nerve made its appearance. The pain of which the patient complained was "cramping" and "shooting" and was aggravated by lying on the back and by walking. Coughing and sneezing likewise accentuated the discomfort. In the two weeks prior to her admission she had needed crutches in order to get around. Treatment elsewhere had consisted of heat, massage, diathermy, chiropractic adjustment, caudal analgesia, manipulation under anaesthesia, and application of a body cast for two months. Analgesic drugs also had been used without relief of the pain.

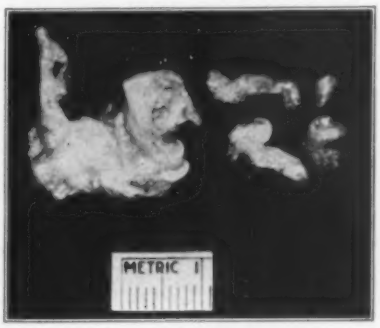

FIG. 11

Protruded portion of lumbosacral disc. The largest specimen popped out in one piece. The other tissue represents fragments of the same disc.

On examination, Lasègue's sign was positive on the left and there was slight exaggeration of the lumbosacral curve. Neurological examination was negative. Spinal fluid obtained on lumbar puncture was normal and contained twenty milligrams of total protein per 100 cubic centimeters. There was no evidence of subarachnoid block.

Roentgenograms of the thoracic and lumbar spine and of the pelvis were negative. No foci of infection were demonstrable. One of us (J. G. L.) was asked to see this patient in regard to further neurological investigation, for it was felt that we were not dealing with an ordinary type of sciatica. When 1-per-cent. procaine hydrochloride was injected into the caudal epidural space, the patient experienced excruciating pain in the distribution of the left sciatic nerve. A caudal lesion was, therefore, suspected and studies with lipiodol were advised, even though the total protein of the cerebrospinal fluid was only twenty milligrams per 100 cubic centimeters and neurological examination was negative. Fluoroscopic and roentgenographic examinations of the spinal subarachnoid space, after the intraspinal injection of five cubic centimeters of lipiodol, disclosed a persistent anterior extradural defect on the left, opposite the lumbosacral disc. At laminectomy on July 8, 1936, protrusion of the fifth lumbar disc was found (Fig. 12). The fifth lumbar root on the left was oedematous, owing to compression by the disc. Extradural removal of the protrusion of the disc was performed and the nerve root was thereby relieved of pressure.

Convalescence was uneventful, and the patient was dismissed from the hospital sixteen days after laminectomy and removal of the disc, free from pain and able to walk without assistance. She has remained free from pain.

Ordinarily one does not consider labor as likely to cause injury to the spine; yet observation of a patient in the second stage of a difficult labor will, we believe, convince anyone that the spine may be subjected to undue stress and strain during this "normal" act. The reverse Queckenstedt

test or epidural injection was the one procedure which led us to the correct solution of the problem involved in this case. In view of the negative neurological examination and the normal cerebrospinal fluid, we had little else to justify fluoroscopic studies with lipiodol.

CASE 5. This patient, a white man, first registered at the Clinic on September 20, 1921, at the age of twenty-five. He said that he had been in an accident in 1918 and had sustained fractures of the right arm and two ribs; he also received a laceration over the right eye. His chief complaint at the time of registration was numbness of the hands and feet, and he dated the onset of this condition as May 1921, at which time he had noted some numbness in the left hand. The numbness then spread to involve the right hand, forearm, and elbow. Involvement on the right side was more marked than that on the left. Shortly after the onset of this numbness, the right hand became weak, and later the fingers of the left hand also became weak. He likewise complained of pain between the shoulders, which was particularly noticeable in the evening.

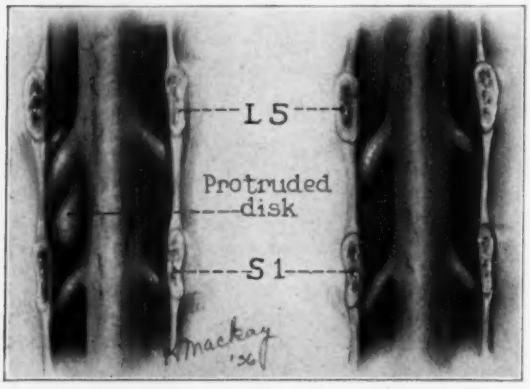

FIG. 12

Showing (left) unilateral protrusion of lumbosacral disc with oedema of compressed nerve root, and (right) nerve freed of pressure after removal of protrusion.

Neurological examination disclosed marked weakness of both right extremities and very slight weakness of the left extremities. Fibrillary twitchings were marked in the muscles of the right upper arm. There was a very slight disturbance of all qualities of sensation below the clavicles.

Cerebrospinal fluid obtained on lumbar puncture gave a negative Wassermann reaction and a positive globulin test, and there was one small lymphocyte per cubic millimeter of fluid. Total protein was not determined. There was no subarachnoid block. The patient was examined several times and many physicians saw him in consultation. The clinical picture was so unusual that this note was made: "Even on repeated examinations and going into the history the etiology of such a peculiar picture is unknown." The provisional diagnosis was myelitis with peripheral neuritis. Other lesions considered were syringomyelia and intramedullary neoplasm. Foci of infection were removed and the patient was advised to have a re-examination if he did not improve.

The patient returned to the Clinic on January 25, 1922, complaining of progression of all symptoms. Both lower extremities were spastic and ataxic, and the right upper extremity was also spastic. Bilateral Babinski reflexes were demonstrated. There was only a slight increase in the disturbance of sensation. The opinion at this time was that the patient had a progressive intramedullary lesion at the fifth or sixth cervical segment, probably a tumor or possibly a central gliosis. The findings were not typical for syringomyelia. On February 18, 1922, cervical laminectomy was performed by Dr. Adson and an anterior extradural cartilaginous tumor was removed. This tumor was attached to the intervertebral disc between the fifth and sixth cervical vertebrae. Following operation, the patient had an uneventful convalescence, and one month later there was marked subjective and objective improvement. He could use his hands more effectively, he walked better, sensation was practically normal, and both plantar reflexes were flexor. There was no sphincteric disturbance. The patient continued to improve and at present,

fifteen years later, he is working and earning his livelihood without any evidence of recurrence of the former trouble.

This is the case illustrated in Dr. Adson's article [1] on tumors of the spinal cord which was published in 1925. Prior to this operation, Dr. Adson had removed a protruded lumbar intervertebral disc in two other cases; in both cases operation was performed because of symptoms and signs suggesting a neoplasm of the cauda equina.

This patient, of course, should have been operated on at the time of his first visit to the Clinic, but diagnosis then was impossible, or at least it seemed to be. Today, when we are determining the total-protein content of the spinal fluid routinely in cases of suspected tumor of the spinal cord, this type of a case undoubtedly would be diagnosed earlier. No doubt the total protein was elevated in this case, and now fluoroscopic study of the spinal canal with lipiodol would be made.

RESULTS OF THE OPERATIVE REMOVAL OF PROTRUDED INTERVERTEBRAL DISCS

When an intervertebral disc is found to be protruded and is causing compression of one or more nerve roots or of the spinal cord, the surgical removal of that disc is followed by an excellent result in the great majority of cases. We have reason to believe also that this excellent immediate postoperative result will be permanent. We have in our series at the Clinic several patients who were operated on as long as fifteen years prior to this study and who have had no recurrence of their former symptoms.

In his article on chondroma of the intervertebral disc, Bucy [5] stated that there were two recurrences in one of Dr. Adson's cases. It is true that the patient to whom Bucy referred had recurrent symptoms which necessitated two subsequent laminectomies, but, after a very careful review of this patient's record and after discussing the case further with Dr. Adson, we are of the opinion that there was no true recurrence of the protruded disc. The secondary operations were essentially decompressive laminectomies for the removal of hypertrophied bone which was encroaching on the cauda equina [18]. At one of these subsequent laminectomies, Dr. Adson did remove some more disc tissue, but he felt that it was tissue that had been left behind originally, and he feels that the operation as we are now doing it will not result in recurrences. Then, too, owing to the fact that the condition is being recognized earlier, the operation is more easily performed and the results should be just as good or better than they have been in the past. In earlier cases in this series, patients were not operated on until more or less classic symptoms and signs of tumor of the spinal cord had developed. By this time the protrusion was large and very fibrous, and removal was difficult. If the condition is recognized during the stage of unilateral root pain, the protrusion is smaller and less fibrous, and its removal is relatively easy.

There has not been a postoperative death in this entire series, and this is all the more striking when one stops to consider that the surgical

removal of a protruded disc is at times much more difficult than is removal of a spinal-cord neoplasm. Also, the institution of drainage in the laminectomy wound is more often necessary in the case of a protruded disc, and one naturally would expect a slightly increased risk on this account.

There has been only one postoperative hemorrhage. This necessitated reopening the wound and the removal of an extradural hematoma. This patient made a complete recovery following this complication and has been entirely relieved of the sciatic pain for which the original operation was performed.

Of the fifty patients in this study, thirty-three have been completely relieved of the symptoms for which the operation was advised and performed. Fifteen have been benefited but not completely relieved, and two patients received no benefit from the operation.

The last two groups are very interesting and deserve further analysis. One of the patients who received no benefit from the operation was a woman, twenty-six years old, who was operated on in 1928 for protrusion of a disc between the sixth and seventh thoracic vertebrae. This patient had been paralyzed in the lower extremities and sphincters for two years prior to operation. There was a decubitus ulcer over the sacrum at the time of operation. At laminectomy, so much damage to the cord was apparent that little improvement could be expected. The disc was not removed but was decompressed. This patient died one and a half years later. The other patient who received no benefit from operation was a man, fifty years of age, who had had backache for twenty years, following an injury to his back, and recurrent sciatica for twelve years. During the neurological examination, it was recognized that this patient had a muscular dystrophy. Fibrillary twitchings were marked. Because of the increased total protein in the cerebrospinal fluid and the presence of a persistent defect in the subarachnoid column of lipiodol consistent with a protruded disc, laminectomy for removal of the disc was advised in the hope of thereby relieving the patient of his pain. At the time of laminectomy, the protruded disc was found to be very fibrous and its removal was difficult. The patient's convalescence was prolonged and, as has been said, he did not benefit by the operation.

Of the five patients who had protrusion of a cervical disc, all were relieved except one and this one has already shown marked improvement. This patient, a girl sixteen years of age, was totally disabled on admission and she was operated on too recently to tell what the ultimate result will be. She had spastic paraplegia with a sensory level at the first thoracic segment and had not walked for six weeks. She had slipped and fallen on the ice about five months prior to the onset of her symptoms, and there had been rather rapid progression of her condition for five months. On September 29, 1936, Dr. Craig removed a large protrusion of the sixth cervical disc, and the patient showed marked improvement. At the time of dismissal, she was able to walk. At operation, in this case, Dr. Craig noted marked compression of the cervical portion of the spinal cord and,

for that reason, he was conservative in his prognosis. The patient's progress to date, however, has been very gratifying.

Besides one case already described, there were four other cases of protruded discs in the thoracic region, in which the patients were not completely relieved. One of the patients was a man twenty-six years of age, who had been unable to walk for eight months, and after removal of the protruded disc there was only slight improvement. Another was a woman of sixty years, who was paralyzed from the waist down. Following removal of a protruded sixth thoracic disc, she obtained relief from the pain between the shoulders, but the paralysis persisted. She died six years later without evidence of further progression in the condition of the spinal cord. A man of fifty-two years had a protruding fifth thoracic disc removed in 1922, but the Brown-Séquard syndrome persisted after operation. This patient is still living.

Another patient, a man sixty-three years of age, came to the Clinic because of pain low in the back and abdomen with projection down the right leg. There was partial paralysis of the lower portion of the right leg. At operation, protrusion of the eleventh thoracic disc was demonstrated. The disc was not removed; instead, a decompressive operation was performed because of profuse bleeding during the course of exposure. This patient has shown marked improvement and is able to carry on his work.

There were ten patients in this series with protrusion of a lumbar disc, who, following operation, were benefited but were not completely relieved. One was a woman of forty years, whose disc was decompressed by laminectomy and removal of an adjacent facet. There was some improvement, but relief was not complete. This patient was of a nervous temperament and had a reactive depression following operation. Another patient in this group was the one with the questionable recurrence, in whose case two subsequent laminectomies were necessary because of hypertrophic osteoarthritis. A third patient, a woman of thirty-one years, who had had pain in the back and both lower extremities intermittently for six years, was definitely improved following removal of a protrusion from the fourth lumbar interspace; she still, however, has some sciatic pain.

The case of one patient, that of a man of forty years, presented a medicolegal problem. He had been struck in the back by a heavy piece of timber two years before registration, and he complained mostly of pain in the back. Roentgenograms disclosed a narrowed fourth lumbar disc. There was a congenital anomaly of the lumbosacral joint with slight anterior displacement of the fifth lumbar vertebra on the sacrum. This patient had previously undergone operative fusion of the lumbosacral joint and arthrodesis of the right sacro-iliac joint, without relief. Immediately following removal of a protruded fifth lumbar disc, the patient stated that he was free from pain, and he walked without the support of the cane which he had used prior to laminectomy. At the end of two months, however, he returned to the Clinic and said his back bothered him, and later he resumed the use of his cane.

A man of fifty years has been markedly relieved by operation, but he still complains of aching in the backs of the thighs. Another patient, a man of forty-five years, was relieved of sciatic pain but has some low-back pain unless he wears a sacro-iliac belt. Prior to operation, this support had not afforded relief. Another patient, a man of fifty-four years, had had pain in the back with recurrent bilateral sciatic pain for twenty-four years. Roentgenograms disclosed narrowing of the lumbosacral disc. It did not seem that his symptoms were on a neurological basis. However, five days following a bone-graft operation for fusion of the lumbosacral joint, there was evidence of a complete transverse lesion of the cauda equina below the level of the fifth lumbar nerves. A protruded lumbosacral disc was demonstrated on study with lipiodol. Unilateral laminectomy, without removal of the protruded disc, was performed. The operation was very difficult, owing to the presence of the recently placed bone graft which was not disturbed. There has been some improvement, but not complete relief.

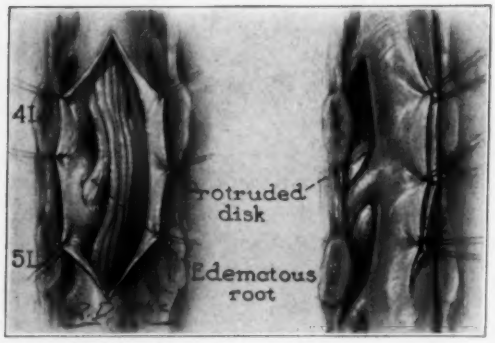

FIG. 13

Unilateral protrusion of fourth lumbar disc with marked oedema of fourth lumbar nerve on the left.

A woman of thirty-one years came to the Clinic with severe soreness across the sacrum, pain down the right leg, paraplegia, saddle anaesthesia, and loss of sphincteric control. A protruded fourth lumbar disc was removed, with very gratifying results. There was almost immediate improvement in power and in sensation. The patient was able to walk without assistance and she could empty her bladder. She still, however, has some pain on sitting.

A man of fifty-two years had had recurrent attacks of left sciatic pain for five years. All of the usual, and some of the more recent, methods of treatment had been employed, without benefit. At the time of operation, one of the largest specimens of protruding disc in our collection was removed from the fourth lumbar disc. This protrusion was removed extradurally from under the fourth lumbar root on the left. The root was very oedematous as a result of compression by the disc (Fig. 13). The arachnoid and dura mater were adherent over the dome of the bulging disc. There was immediate and complete relief from symptoms; however, we have recently learned that this patient is having some pain in the leg.

The last patient in this group was a man of forty-one years, who, in addition to low-back and sciatic pain, had symptoms and signs of spondylitis. Studies with lipiodol disclosed protrusion of the fourth lumbar

disc into the spinal canal. It was appreciated that removal of the disc would not cause disappearance of all the symptoms and, after the problem had been explained to the patient, laminectomy, with removal of the protruded portion of the disc, was performed. Much to our surprise, all of the patient's symptoms disappeared following operation. Two months later, however, he began to complain of pain in the back and of a feeling of tightness in both legs, which undoubtedly was an expression of activity of the spondylitis.

SUMMARY AND CONCLUSIONS

In a series of fifty consecutive cases in which laminectomy for removal or decompression of a protruded intervertebral disc has been performed at The Mayo Clinic, the results have been very gratifying. These patients were selected from a large number of individuals who came to the Clinic with various types of chronic pain. For the most part the pain resembled that which results when a spinal-nerve root is compressed.

There was not a postoperative death in the series.

Protrusion of an intervertebral disc is a definite anatomical and pathological condition. It is usually the result of trauma which may be slight or severe. The most common symptom of such protrusion is pain along the course of one or more spinal nerves, most often the sciatic nerve.

The diagnosis is made by roentgenographic examination of the spinal canal after the introduction of a radiopaque oil into the subarachnoid space. The treatment of choice is laminectomy, with removal of the protruded portion of the disc. Decompressive operations without removal of the disc are not advised.

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THE COMPENSATION ASPECTS OF LOW-BACK CONDITIONS*

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The present status of these back problems, as far as the insurance companies are concerned, is not flattering. It may be summed up in a quotation from a letter received last month from the surgical head of one of our largest insurance companies: "With the difference in the compensation laws in the various states, it is difficult to evaluate our final results but it does seem as though, in the treatment of these injured backs, we are no nearer a solution than we were a number of years ago." The head of another large company says: "I am free to admit that we are often undecided as to the proper course to pursue in these back cases. As a matter of fact, in 75 per cent. of these cases, we compromise without resorting to any operative procedure and settle them for a lump sum." I should say that they are bewildered by the multiplicity of ideas about back conditions held by the medical profession. Again quoting: "One of the greatest difficulties with which we have to deal is to obtain a correct diagnosis. In a number of instances these industrial cases are examined and reported upon by outstanding specialists and we are confronted with reports in regard to the conditions found and proposed treatment, often surgical, completely at variance one with the other." Quoting from another company: "A great many methods of treatment have been used in compensation cases, none of which, apparently, so far as relief is concerned, has accomplished its purpose. One method of treatment is just as good as another—it would appear that there is no choice."

I believe that the crux of the difficulty lies in the fact that every case presents a combination of factors—psychological and anatomical. Not until both factors are given due and proper consideration are we going to achieve much better results than we have to date.

The compensation case is often influenced by racial traits which we cannot change and about the handling of which we know little, by marital conditions, and, particularly, by economic conditions. Think of the strain on an injured man's ethics during the past seven years when to get well meant to give up compensation and become jobless! We all saw how hard it was to get the better placed individual off a paying accident policy.

Doctors talk about traumatic neuroses in these back cases. John Doe stoops to lift a box and gets a catch in his back. For weeks, months, years he is afflicted by steady pain—severe enough to prevent working but not bad enough to keep him from gaining weight and looking hale and hearty while he draws fifteen or twenty dollars a week. He gradually develops quiverings and twitchings and a woebegone look when he is at

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 14, 1937.

hearings. Dumb as he is, he learns that, on examination, certain activities on the part of the examiner call for certain responses on his part. He can always find a doctor who will agree that, while objective symptoms are lacking and it is curious that so slight an injury should cause so long a period of disability, he is unable to return to work. He has a traumatic neurosis. If the question of the possible effect of the fifteen or twenty dollars per week is brought up as a factor in this neurosis, it is brushed aside as being of no moment,—it is probably just a capitalistic myth.

Compensation laws are rightfully designed to protect the claimant and he should have the benefit of the doubt, but his advantage may become too great when a lay commissioner has the final decision as to whether the claimant is disabled.

If employers could and would help us in handling these back cases, some gain would be made. Small employers often cannot and large employers often will not take these men back at light work—that is, work requiring little strain on the back—for a period of several weeks and then let them gradually get hardened again. This, in many cases, would be a helpful procedure.

It is with some feeling of hesitancy that I come before this group to discuss problems in regard to low-back conditions. This Academy does not represent a cross-section of Medicine,—it certainly considers itself the cream off the top. Yet I dare believe that a given case could be presented to this Academy and as many different diagnoses and corresponding methods of treatment would be suggested as there are groups allied by training in the Academy. The development of our present knowledge of the low back is interesting. I have lived through most of it. The hypothesis of sacro-iliac strains and displacements was the gleaming star leading its disciples onward and upward. This was so in Boston, to a lesser extent in Baltimore, and with diminuendo effect in Philadelphia, New York, and Chicago; it disappeared entirely in Toronto and Montreal. It puzzled me as to how sacro-iliac subluxations could be so generally believed in in Boston and Baltimore, and not be accredited in New York and Chicago. I saw them manipulated in Boston with due regard to what the roentgenogram showed. In Baltimore, with equal enthusiasm, the surgeons manipulated all cases in the same manner. In practice I was struck with the uncertainty of results and wondered if there might not be mistakes in diagnoses. About sixteen years ago, it was our good fortune to have the Interurban Orthopaedic Club meet in Rochester and, within three minutes, I was shown a roentgenographic demonstration of sacro-iliac subluxation on the left side of the pelvis by a Bostonian, and a sacro-iliac subluxation on the right side of the same pelvis in the same roentgenogram, by a distinguished gentleman from Baltimore. This rather confirmed my growing doubts as to the certainty of our knowledge about sacro-iliac lesions. Now sixteen years have passed and, during this time, great advances in diagnosis and treat-

ment have been made. Much has been contributed to the anatomical knowledge of the lower back; perhaps more to the theoretical possibilities of treatment. With the development of these ideas, emphasis has been placed on surgery as well as on various other methods. Among the many forms of treatment which have been suggested are: epidural injections of saline or of novocain used in certain parts of the country; fusion of the sacro-iliac joint by various techniques—each and every modification vouched for by its parent; fusion of the lumbosacral region by the Hibbs or Albee technique, with various additions by equally enthusiastic parents; fasciotomy; and now spinal exploration for extrusion of the intervertebral discs.

Still the insurance companies are in trouble, as shown by the following quotation: "For instance, we may have a diagnosis of a sacro-iliac condition. The surgical treatment proposed is stabilization of the sacro-iliac joint. On the same case another surgeon makes a diagnosis of a ruptured intervertebral disc and the treatment suggested is an operation on this disc. We have half a dozen cases, in various parts of the country, where a diagnosis has been made of a ruptured intervertebral disc following lipiodol injection into the spinal canal. We have cases where such a diagnosis was made and operations were performed by some of the finest neurological surgeons in the country, and the condition diagnosed was not found. In one of these cases a stabilization operation on the lumbosacral joint was performed in 1934 and the man is still disabled. In another instance, in one of the big clinics of the country, diagnosis of a lumbosacral condition was made and lumbosacral stabilization was performed. Symptoms persisted following the operation; diagnosis of a ruptured intervertebral disc was then made. Operation was performed and such a condition found. The end result is not yet known. In another case, in an Eastern state, two outstanding orthopaedic surgeons examined a man; one suggested a stabilization operation for the sacro-iliac joint and the other advised an operation for a ruptured intervertebral disc. These diagnoses were made within a day or two of each other."

I think it has long been recognized that, with rare exceptions, it is not good judgment to go to the parents of the child to find out the child's faults. The mental parent of an operative procedure is liable to have a biased opinion of its value, especially if it is taken outside its home circle.

Recently I have had opportunity to study the end results of a fairly sizable group of cases recorded by one insurance company. Of six cases of sacro-iliac fusion in which the results were classed as fair, one case is not yet settled. This patient has been disabled for four years following the operation and for six years after the injury. The other five cases were finally settled with an average permanent disability of 73 per cent. after periods varying from four to ten years. There were eight cases of lumbosacral fusion in which the results were called fair; these were settled with an average permanent partial disability of 51 per cent. In five cases of sacro-iliac fusion the results were classed as poor. One

patient died; three are still disabled after an average period of eight years; and the remaining patient is now considered to have a fair result. There were seven lumbosacral fusions with poor results; these cases were settled with an average permanent disability of 84 per cent. In seven cases of lumbosacral fusion by the method of Hibbs good results were obtained; five patients returned to work in an average of nine months postoperatively. There were twenty cases the results of which were classified as good, fair, and poor, but, when analyzed, it was found that two patients had no permanent disability; six were given 10 per cent. permanent disability; one was given 5 per cent. permanent partial disability; and the remaining eleven cases were settled with a permanent partial disability averaging 40 per cent. In these cases the operations were performed by experienced surgeons,—probably most of them were members of this organization or of similar ones, and it is this sort of an experience which leads to the following quotation: "Following an observation of fifteen years in the diagnosis and treatment of low-back conditions, it is our opinion that, with a few exceptions, conservative treatment has shown better results than operative treatment." Why should this be? Either our knowledge of anatomy is faulty, or our interpretation of its indications is wrong, or else we have taken the intangibles, mentioned earlier, into too little consideration.

It seems to me that, at the present time, the question of injury to the disc with extrusion of part of it into the spinal canal is very important, but there are serious questions to be answered before the rank and file of surgeons adopt it. First, what effect will four or five cubic centimeters of lipiodol have if left in the spinal canal? I have asked a number of neurologists and they do not know. Second, can these extruded parts be removed without leaving a weak back? There is little advantage to the claimant or to the insurance company if a brilliant operation is done and the claimant is no more able to do active work than he was before. These questions cannot yet be answered.

I feel sure that there are certain members of the profession, who, because they are selecting their cases with great care after a careful diagnosis, and because they are skillful operators, can solve some of these back problems satisfactorily. However, having listened for many years to papers on low-back conditions and having read others, I find myself in the position so well expressed by Omar Khayyam: "Myself when young did eagerly frequent doctor and saint, and heard great argument about it and about; but evermore came out by the same door as in I went."

It is upon the first medical man who sees the injured back that much of the responsibility for the after-results falls. I believe that all of these backs should be rested. Frightening the individual or fixing in his mind the idea that he has a serious back injury should be meticulously avoided. Strapping the back and urging the patient to return to work as soon as possible are, I believe, the causes of much of our difficulty in later cases, in spite of the statement of the head of one of the insurance companies

that he is impressed by the better results that osteopaths obtain because they minimize the condition and do not frighten the injured man into feeling that he has a serious lesion. Strapping and a few days' rest on a hard bed with the application of a little local heat—perhaps relaxing the patient completely with morphine for the first forty-eight hours—will enable the patient to get back to work when he feels that he can. He has a feeling of having been well cared for and his inclination is to return to work. The psychological character of the individual, as well as his physical condition, should be taken into consideration in every case. If the injury has occurred to a spine already showing the ravages of hypertrophic arthritis, due consideration to that fact must be given. In compensation cases, I am continually struck by the importance of keeping the attitude of the patient right. The doctor may not be able to do this; fancied injustices on the part of the employer may make it very difficult.

The application of casts and the use of braces, I believe, are fraught with peril. Certainly before employing either form of treatment, one should be very sure that the advantages to be gained will outweigh the possible harmful effects on the patient. It is always well to look back and realize that casts and braces, which were believed in so thoroughly by the older generation, have, in most instances, failed to accomplish what they were supposed to have done. I often think of the situation in regard to scoliosis,—men wrote books on the treatment and cure of scoliosis, illustrating plaster jackets and braces that pressed here and pulled there, but, on final investigation, no case of cure was shown.

When it comes to the question of the need or the advantage of surgery in low-back conditions, we should deliberate most carefully, because, if we give certain types of individuals a scar, they will never get out of the compensation class.

LOW-BACK LESIONS

Closing Remarks by the Chairman*

BY JOEL E. GOLDTHWAIT, M.D., BOSTON, MASSACHUSETTS

A symposium of this type, dealing with a symptom which is probably the most common that is met by the physician, naturally should lead to the consideration of the subject in the broadest possible manner.

In the first place, it should be recognized that backache usually means strain of the joints of the back with, at times, so much pressure upon the nerve roots that referred pain results. In such a discussion, all conditions which might contribute to symptoms of this type should be considered and, representing the gynecological point of view, Dr. Frank H. Pemberton, Professor of Gynecology at the Harvard Medical School, has written stating that backache due to purely gynecological conditions is relatively rare. A similar statement has been received from Dr. Edward L. Young, representing the urological point of view. It is apparent, therefore, that, while the diseased conditions of the pelvic organs or of the genito-urinary tract in men or in women may at times be associated with backache, usually in these cases the other symptoms are so conspicuous that there is very little question as to the main source of the difficulty.

In any discussion of the subject of backache, naturally the first consideration should be the structure of the spine itself, especially with reference to the low back. A study of comparative anatomy shows that the number of vertebrae in the lumbar region, as seen in the lower orders, varies considerably from the many lumbar vertebrae in certain orders to the few in others, and that these changes occur at the thoracolumbar level or at the lumbosacral level. Since this is the case, variations in the shape of the bones, as well as in the number of the vertebrae in the lumbar region, should be more or less expected in the human spine. These anatomical variations are many times of much importance in the production of symptoms, as well as in the treatment required to give relief. Too much attention or care cannot be given to this phase of the difficulty before starting upon any course of treatment in the individual case. We are very fortunate in having this aspect of the subject presented by Dr. Willis.

It should be remembered that these anatomical peculiarities have existed since birth, but, as a rule, the individual seeks treatment in the adult periods, which means that the anatomical peculiarities are probably only part of the problem. In considering the elements which make them a special source of difficulty, probably the most common is the imperfect use of the body, so that the weight-bearing points in the low back are abnormal. In practically all such cases, the lumbar spine, especially at the

* Symposium presented at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Cleveland, Ohio, January 14, 1937.

lumbosacral level, is used in the position of extreme extension—a position which is one of strain under the best conditions—and if anatomical peculiarities exist, the development of symptoms should not be a matter of surprise. Therefore, once the anatomy is understood, there should be insistence on the improvement of the mechanics of the region, so that the best possible function may be expected. In the consideration of this aspect of the difficulty, we are fortunate in having Dr. Brown present the subject.

At times the anatomical peculiarities are such, and the joint strains have existed for so long, that surgery, with the idea of fusing one or more of the joints, becomes necessary and we are fortunate in having Dr. Compere present this phase of the problem. With reference to this it should always be remembered that, if it becomes necessary for one joint to be fused, some other joint is obliged to take up the work which that joint formerly performed, and it should be appreciated that the joint which has the added strain put upon it may many times cause as much difficulty as was previously present.

The chief point that seems to me important with reference to surgery of the spine, or to fusions of the joints, is to be perfectly sure that the lumbar spine is flattened, or that the joints are in the position midway between full extension and full flexion. In this position the muscle balance will not be disturbed and there is more likelihood of obtaining excellent end results. To fuse until this has been accomplished means fusing the spine in a deformed position and the last state of the individual may be worse or no better than the first.

In connection with the fusion, it should be remembered that probably there are very few in this room who have not had more or less backache, but probably few, if any, have felt it necessary to have the back fused because of this.

Another feature which is a definite part of such a symposium is a condition which has received general recognition only comparatively recently, but which was described by the Chairman a good many years ago,—namely, the backward displacement of the intervertebral disc, or the nucleus pulposus. As the result of Schmorl's work, this has received renewed attention. In considering this feature of the back problem, it should be recognized that always when the nucleus pulposus is squeezed backward the lumbar spine, especially at the lumbosacral joint and the joint above, has been used with the bones in the position of extreme extension. This narrows the space between the vertebrae at the back, and the nucleus pulposus is, apparently, squeezed, with the result that it breaks through the posterior portion of the controlling ligament. It should be appreciated that this ligament which holds the nucleus pulposus in its proper shape is much thinner in the posterior part in front of the spinal canal than around the sides and front. This naturally means that, if the nucleus pulposus is compressed, the weakest place for it to squeeze through will be at the back.

In operating with the idea either of removing the displaced portion or of simply doing a laminectomy and relieving the pressure by taking away the arch of the bone, it should be remembered that many times the articular processes are so placed that they project over the spinal canal, especially at the lumbosacral level, with the result that, even though a laminectomy is performed, it does not necessarily relieve the pressure of the extruded portion of the intervertebral disc at the sides. For this reason, in this type of case, as well as in the cases in which fusion is to be done, the lumbar spine should be flattened so that there is the least abnormal compression upon the intervertebral disc tending to crowd the nucleus pulposus out of place. Undoubtedly, some of the disappointing results of operation in cases in which this condition has existed are to be explained in this way. We are fortunate in having the surgery of this condition so ably presented by Dr. Love.

The subject of acute back strains or injuries, including the industrial accidents and compensation features, has been presented by Dr. Prince in a way that should cause us all to appreciate how serious this phase of our work is, and how unsatisfactory much of the treatment of these cases has become. It seems to me that the most important thing for us to realize is that most of these cases represent a joint sprain and that the lumbosacral and the sacro-iliac joints are most commonly affected. Because of the structure of these joints, it is, of course, extremely difficult to protect or to fix them with the patient up and about. The result is that, as most of these cases are handled at the present time—either comparatively little attention is given in the early stages or treatment consists merely of strapping the back or administering drugs—the congestion of the part incidental to the sprain is continued, and, instead of an acute sprain, in a comparatively short time a chronic condition results. Once such a condition develops and the compensation features are added, with the many examinations that are involved, it is easy to understand how unsatisfactory the treatment and handling of these cases is, irrespective of the method.

As has been suggested by Dr. Prince, if such cases could be treated as any other acute sprain is treated—namely, with protection for a few days, long enough for the acute congestion to subside, and then a few days longer for the healing of the ligament to occur—most of these patients would return to their ordinary activities in a comparatively short time. Since it is almost impossible to use any form of support that will satisfactorily protect these joints when the patients are up and about, it seems to me, as it apparently does to Dr. Prince, that these patients should be put to bed for a week or ten days, with any form of local application to the low back that will stimulate the circulation, and with the expectation of a rapid recovery and the ability to return to work in a comparatively short time. It should be stated to such patients that there will undoubtedly be some backache or back pain for a short time, as would be expected in treating any other sprained joint. With such handling, it seems to me

that most of these cases become simple, and they do not present the difficult type of problem, or call forth reproach, as they certainly do in the minds of Compensation Boards at the present time.

As a whole, it should be recognized that low-back pain is common, and that simple manipulations often relieve the symptoms but rarely ever cure them. It should also be recognized that operations many times relieve pain, but, unless they are performed with the full appreciation of the anatomical structure and the mechanics of the back, the end results are disappointing. On the other hand, if all of the features which have been presented in this symposium are considered, probably fewer of the cases will be operated upon and the treatment of these cases as a whole will represent a greater credit to our profession than they do at the present time.

MULTIPLE EPIPHYSEAL ANOMALIES IN THE HANDS OF A PATIENT WITH LEGG-PERTHES' DISEASE

BY CARROLL O. ADAMS, M.D., CHICAGO, ILLINOIS

From the Division of Orthopaedic Surgery, Department of Surgery, University of Chicago Clinics

The etiology of osteochondritis deformans juvenilis (Legg-Perthes' disease) is not established. The theories to explain its occurrence are not accepted by all. The epiphyseal system in individuals with the disease, therefore, deserves study and the finding of multiple rare anomalies of epiphyses of such individuals deserves reporting.

CASE HISTORY

A. C., male, aged nine years, the child of Greek parents, was first seen in the Out-Patient Department on May 2, 1934. A diagnosis of osteochondritis deformans juvenilis was made from the history, the physical examination, and the roentgenograms. The patient was advised to wear a hip spica cast and to stay in bed.

He was next seen on November 2, 1934. At this time he reported that he had worn the cast only three months after which he had been up and about. The symptoms had returned. He was admitted to the University Clinics and has been kept under observation since that time. The lesion has healed and the patient is now ambulatory, without a limp.

During a roentgenographic study of the carpal bones of grossly normal hands, anomalies of the hand skeleton were found in this patient. Subsequently, the rest of the skeleton was x-rayed and found to be roentgenographically negative except for the diseased right hip. The patient is left-handed and the two hands appear entirely normal except for a medial deviation of the distal phalanx of both index fingers of about 30 degrees (Fig. 1). The anomalies found, as illustrated in Figure 2, include:

1. Double ossification center for os lunate, bilateral.
2. Distal epiphysis of first metacarpal with partial fusion to the diaphysis, bilateral.
3. Proximal epiphysis of second metacarpal with beginning fusion to the diaphysis, bilateral.
4. Suggestion of fused proximal epiphysis on fifth metacarpal, bilateral.
5. Distal epiphysis on all the first row of phalanges and on the second to fifth inclusive of the second row.
6. Growth

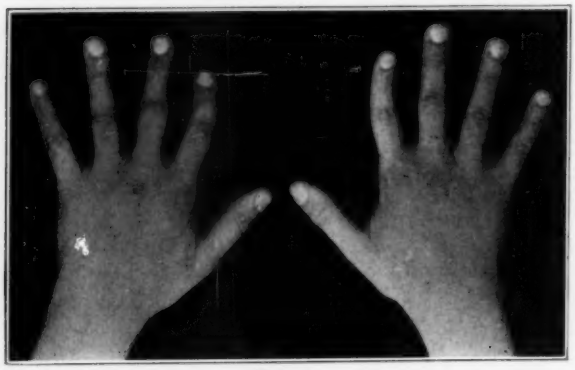

FIG. 1

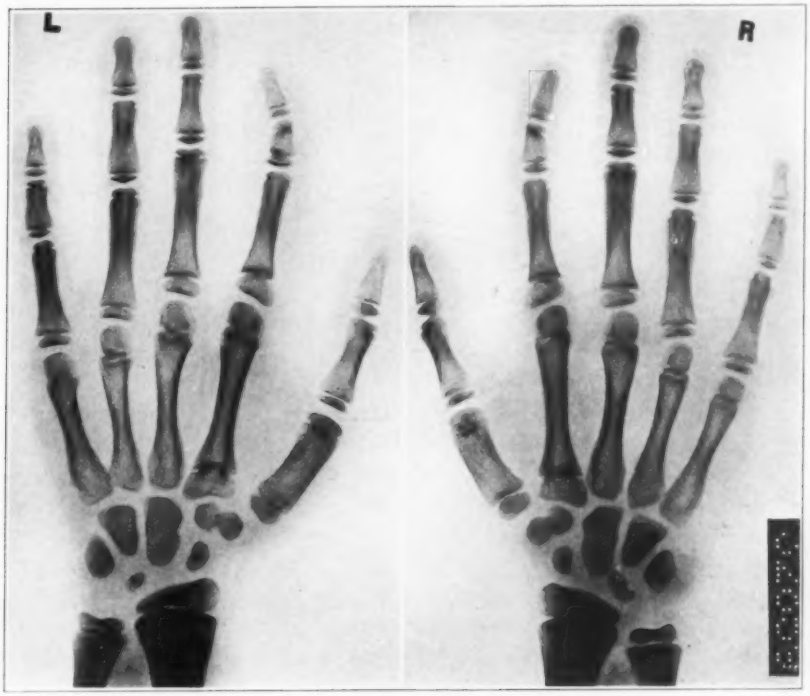

FIG. 2

arrest on the medial side of the distal epiphysis of the second phalanx of the index finger with resultant medial bowing of the finger, bilateral.

The double ossification center for the lunate represents two distinct bones. The accessory bone is definitely not the anomalous so-called "os centralis" which is described by Gray and others as lying between the lesser multangular, capitate, and navicular, for in this case the bone is distinctly in the position of the lunate, lying either above or below it. Carter speaks of an epilunate, or hypolunate, but in this case the accessory bone is as large as the lunate itself, so that it is impossible to state which is the normal bone and which one is the accessory. Roentgenograms at a later date may clarify this point. This duplication of the lunate bone is so uncommon that there are no statistics showing its incidence.

A distal epiphysis on the first metacarpal appears in about 40 to 50 per cent. of male children in the group ranging from eight to eleven years of age and less commonly in females.[1, 3]

A proximal epiphysis on the second metacarpal is present in a small percentage of normal children. Carter reports the incidence of from 1 to 2 per cent. On the fifth metacarpal it is less common.

Epiphyses on the distal ends of the first and second rows of phalanges are also uncommon. Most writers do not even mention this anomaly.

From a study of 2,700 roentgenograms of the hand, Stettner tabulated the number of anomalous epiphyses which he found in the metacarpals and phalanges as follows:

Location		*Cases*
Metacarpal	II	434
"	III	37
"	IV	22
"	V	168
First Phalanx	I	24
" "	II	5
" "	III	10
" "	IV	11
" "	V	8
Second Phalanx	II	6
" "	III	6
" "	IV	29
" "	V	128

These figures are considerably higher than those of most authors, probably because they included a number of cases with multiple congenital defects and anomalies.

The fact that a large number of these anomalies (fourteen in each hand) were found bilaterally in an individual with osteochondritis deformans juvenilis may justify this case report. Perhaps this disease is dependent upon some congenital abnormality of the epiphyseal system as this case might suggest.

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PRIMARY CARCINOMA OF THE LIVER WITH METASTASIS TO BONE

Report of a Case

BY DONALD W. HEDRICK, M.D., DETROIT, MICHIGAN

From the Division of Orthopaedic Surgery, Henry Ford Hospital, Detroit

Primary carcinoma of the liver is seen quite infrequently. This lesion with metastasis to bone has seldom been described.

According to Boyce and McFetridge, something over 600 cases of primary carcinoma of the liver have been reported. Their cases (144) represented approximately 2 per cent. of more than 65,000 autopsies. Seven cases of metastasis of this lesion to bone have been reported by Blumberg, Schmidt, Catsaras, Kaufmann, and Moon. Geschickter and Copeland, in their complete description of bone tumors, report one case of carcinoma of the liver with bone metastasis.

Of interest from its clinical and pathological aspects, the case reported here also presented an unusual surgical picture. At operation, the metastatic lesion was found to have invaded bone at each side of the involved joint.

Fig. 1

Showing destructive lesion of right sacro-iliac joint.

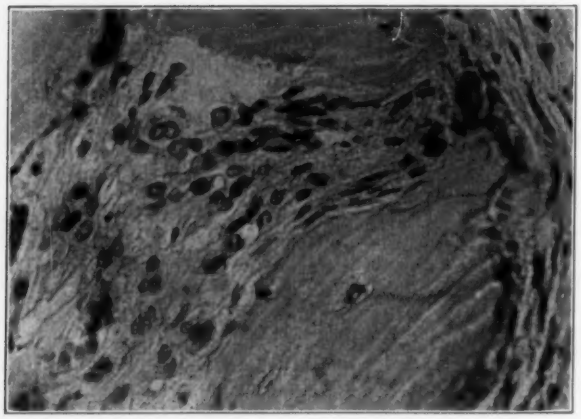

FIG. 2

Metastatic-carcinoma cells invading bone in the sacro-iliac region.

CASE REPORT

A. S. (No. 28412), a male, fifty-eight years of age, came to the Orthopaedic Clinic of the Henry Ford Hospital on May 15, 1935, complaining of low-back pain and pain in the right hip of two years' duration. Treatment had included mineral baths, injection of the sciatic nerve, and vasectomy. Walking was possible only with a cane. Weight loss was denied.

Examination revealed an emaciated adult male. The lumbar spine was flat. Flexion of the spine was made freely and without muscle spasm. Extension was limited. Pain on palpation was present over the right sciatic exit. None was found over the lumbar spine. The right hip resisted passive internal rotation. Abduction of the hip was limited to 5 or 10 degrees, but adduction was normal. Flexion was possible to 80 degrees, but extension was painful. There was pain on pressure over the course of the right sciatic nerve. Reflexes were equal and active. No sensory disturbance was found.

FIG. 3

Lipiodol injected into intrapelvic psoas abscess.

The legs were equal in length and no unilateral atrophy was found. The examination suggested disease of the hip joint rather than of the spine.

Roentgenographic examination (Fig. 1) showed a destructive lesion which involved the inferior part of the right sacro-iliac articulation. No abnormality was found in films taken of the hip.

We were unable to differentiate between malignancy and tuberculosis, and advised exploration, biopsy, and frozen section. If tuberculosis were found, fusion was advised.

On June 12, 1935, the right sacro-iliac region was exposed through a curved incision and the joint proper was exposed by lifting off the posterior superior spine of the ilium. No purulent material was encountered, but in the lower third of the joint an area, yellowish in color and somewhat friable in structure, invaded the bone of the ilium as well as the sacrum. As much of this as possible was removed by curette and gouge.

The postoperative course was uneventful until June 17, 1935, when the patient got out of bed without permission. The operative wound became exposed at this time.

FIG. 4

Sectioned liver, showing primary carcinoma.

The sutures were removed ten days following operation and a small amount of purulent material was found. Culture of this material showed staphylococcus albus. The patient's strength increased for a month, when discomfort in the right leg recurred. By this time the wound had healed except for two small draining sinuses.

The biopsy material was eventually decalcified and sections were described by the pathologist as showing "large irregular cells with pink-staining cytoplasm and large, vesicular, stippled nuclei. Many mitotic figures are seen. These cells are invading the intertrabecular spaces of the bone in solid sheets rather than replacing the bone." (See Figure 2.) A diagnosis of metastatic carcinoma was made.

Because of the discomfort in the right leg, absolute alcohol was injected into the subarachnoid space by the neurosurgeon on November 26, 1935, and again on December 19, 1935. Relief was transitory. No evidence of a primary tumor could be found. One dose of deep x-ray therapy was given.

Three sinuses persisted. On March 18, 1936, roentgenograms, taken following injection

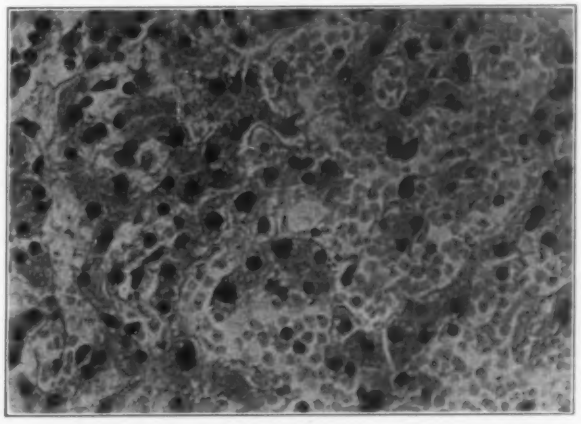

FIG. 5

Liver tissue at periphery of nodule invaded by carcinoma cells.

of the sinuses with lipiodol, revealed an apparent intrapelvic psoas abscess (Fig. 3). The patient's condition grew progressively worse. On April 22, 1936, he had a series of acute abdominal pains which increased in severity until he finally expired with clonic convulsions on April 26, 1936.

Necropsy showed a large abscess in the body of the right psoas muscle. A terminal bronchopenumonia was present. In the dome of the right lobe of the liver was a small firm mass, three centimeters in diameter, which was sharply circumscribed. (See Figure 4.) This mass was densely adherent to, but did not invade, the diaphragm. At the center was a fibrous core from which fibrous strands radiated. Multiple incisions throughout the remainder of the liver revealed no similar nodules.

Microscopic sections of this nodule showed it to be composed mainly of fibrous connective tissue which had undergone extensive hyalinization. In the periphery of the mass were seen a number of neoplastic cells which infiltrated the surrounding liver parenchyma (Fig. 5). These cells were large and had bizarre nuclei which were often hyperchromatic. Occasional mitotic figures were noted. The malignant cells in some areas had a signet-ring appearance and some showed one or more definitely enlarged nuclei. The central portion of the nodule was entirely fibrous, while the peripheral portion showed a moderate number of neoplastic cells.

Microscopic section of tissue from the region of the secondary involvement showed neoplastic cells similar to those described, arranged in small accumulations. Here, there was some suggestion of an adenomatous arrangement. Marked fibrosis had again taken place throughout this area.

Final anatomical diagnosis: Primary carcinoma of liver (bile ducts) with metastatic carcinoma of the right sacro-iliac joint and surrounding tissue.

The diagnostic difficulties and the fact that the metastatic lesion involved and crossed the sacro-iliac joint to invade both the sacrum and the ilium make this case unique.

The author wishes to acknowledge the work of Mr. Neill Graham in the preparation of the photomicrographs used in this article.

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THE TREATMENT OF FLAT-FOOT BY MEANS OF EXERCISE

BY ERNST BETTMANN, M.D., LEIPZIG, GERMANY

The human foot was originally an organ for gripping. Our forefathers had a capacity for walking and climbing which most of us no longer possess. Nowadays, due to the wearing of shoes which cramp the feet and walking on hard pavements, the foot often becomes painful and inadequate to perform its function. In the treatment of flat-foot, exercise is of equal importance with, if not of more importance than, the mechanical supports which are too generally sold to cure individual cases. The purpose of medical exercises is the systematic strengthening of the lifting muscles on the inner border and transverse portion of the arch,—tibialis anterior, tibialis posterior, flexor hallucis longus, flexor digitorum longus, interossei, and peroneus longus. If the foot muscles functioned properly, they would prevent the painful lowering of the arch, and mechanical support would often be unnecessary.

There are two types of gymnastics which may be employed to correct flat-foot:

1. A series of foot exercises which can be supervised by the wise mother, the nurse, or the family doctor.
2. Exercises by means of special apparatus, which permit the amount of the exercise to be increased as much as is necessary for the gradual strengthening of the weak muscles.

EXERCISES

Concerning the first type, the author suggests the following simple foot exercises which may already be known:

FIG. 1-A

Exercise with the medicine ball.

FIG. 1-B
Exercise with a pine cone.

1. Walking with bare feet on coarse and uneven ground (grass, stubbles, and pebbles).

2. Jumping rope; this improves posture and breathing, strengthens the calf muscles, and raises the arch of the foot.

3. Use of the so-called "Spitzy ball" (a wooden ball sewed on a straw sole and worn as a sandal).

4. "Towel exercises", which improve both flexion and adduction.

In order to make the treatments attractive for children, the exercises may be employed in games,—foot gymnastics with the medicine ball and the gripping and throwing of pine cones or chestnuts. (See Figures 1-A and 1-B.) Both games strengthen the musculature of the entire leg. With the help of imagination and experience, it is possible to develop innumerable combinations of exercises.

APPARATUS

The following types of apparatus, which can be made by a good carpenter and mechanic, have as their bases these corrective principles:

1. Fixation of the heel in supination;

2. Pressure of a stable correction cushion against the weakest point in the foot arch,—the talonavicular joint;

3. Regulated adduction and pointed-toe position.

All exercises must be carried out with the knee bent at right angles and the lower leg perpendicular.

The Potter's Disk

It consists of a slanting disk, forty centimeters in diameter, covered with rough rubber. (See Figure 2.) The disk revolves on four wheels and its height is adjustable by means of a screw plate. On the fixed hub there is an adjustable plate for the right and the left foot in supination. A heel clamp, which can be tightened and loosened by means of a screw, helps to fix the heel in position. Both wings of the clamp have adjustable cushions for the redressment of the talonavicular joint. The fixation is maintained by two straps. The amount of flexion can be varied by raising and lowering the disk. Movement of the disk is made difficult by means of a braking weight.

The Foot-Correction Ball

A wooden ball, about twenty centimeters in diameter, is mounted on a round joint, which makes possible its adjustment in every direction. The heel rests on a support. (See Figure 3.) By means of screw *a*, the height can be regulated; by screw *b*, the degree of supination is controlled;

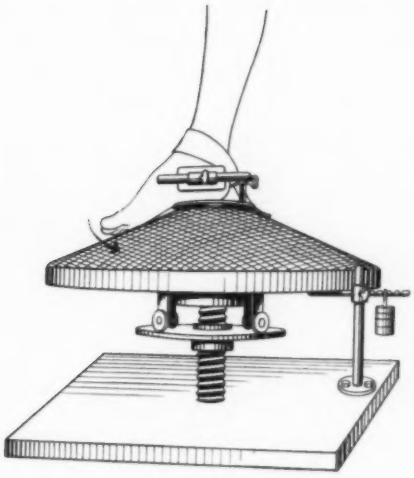


FIG. 2

The potter's disk.

FIG. 3

Grasping exercise with the foot-correction ball.

by screw *c*, fixation of the heel is guaranteed; and by screw *d*, the correction cushion is adjusted. If the axis of the ball is horizontal and parallel to the foot, a "grasping exercise" is afforded, which can be regulated by moving the ball or by elevation of the heel support. If the axis of the ball is vertical and at a right angle with the foot, the foot is obliged to adduct in order to move the ball. The amount of adduction can be regulated in the manner just described.

Apparatus for Limbering Stiffened Flat Feet in Adults

This apparatus is shown in Figure 4. The foot rests on a fixed cushioned stirrup, *a*. A strap cuff, which is laid around the ankle and passed over the heel of the foot, is attached to the lever at *b*. Another strap is laid around the front of the foot and led over a pulley to the other end of the lever at *c*. The attachment of the straps must be made when the front of the foot is in extreme plantar flexion. The axis of the lever is connected with a bar, *d*, which permits the manipulation of the lever so that a corrective pull on the heel and front of the foot is possible. The toes rest on

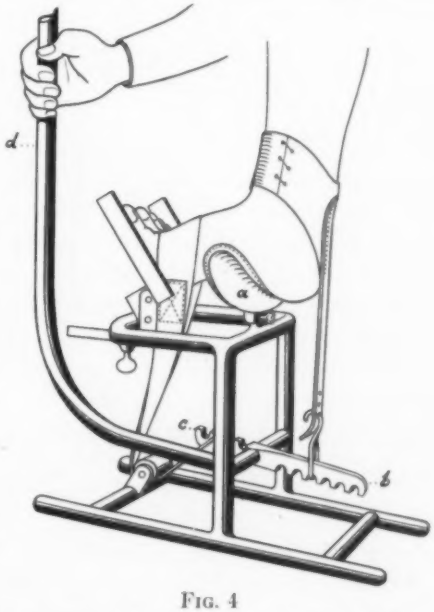


FIG. 4

Apparatus for limbering stiffened flat feet in adults.

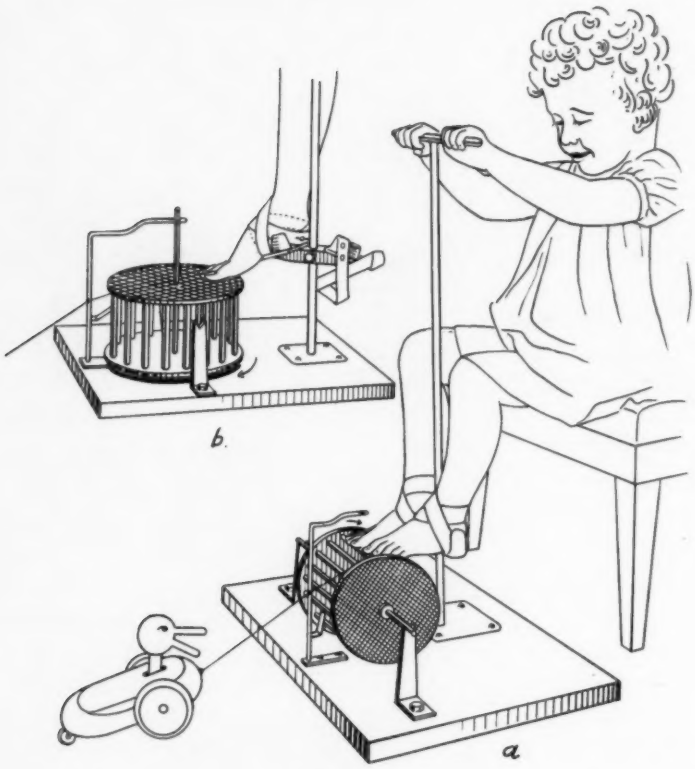


FIG. 5

The turbine wheel:
a: grasping exercises
b: adduction exercises.

an adjustable plate, which fixes and mobilizes them, so that the patient can apply the treatment himself.

The results obtained by the use of this apparatus are: (1) stretching of the Achilles tendon and pointing of the calcaneum; (2) raising of the arch in the talonavicular joint; (3) conversion of the position of the metatarsal part of the foot into pronation; and (4) shortening of the front from toe to heel together with mobilization of the toes. With the help of this apparatus, which can be used from two to three times daily for a period of from twenty to thirty minutes, the author has succeeded in preparing many stiffened and painful feet for the wearing of arches.

The Turbine Wheel

To make foot calisthenics attractive for children, the so-called "turbine wheel" has been constructed. (See Figure 5.) By means of different adjustments it permits the corrective exercise of practically all foot muscles, and it can be used for both the right and the left foot. Two parallel wooden disks, covered with rubber, about twenty centimeters in

diameter, and about thirty centimeters apart, are connected by means of wooden spokes. The resulting turbine wheel is mounted on an axle and supplied with an adjustable brake to guarantee movement in one direction only. On the same plate which carries the turbine wheel there is a metal bar to support the adjustable heel rest. The heel of the foot remains fixed in the rest by a bandage strap and a rubber correction cushion at the talonavicular joint. At the upper end of the bar there is a hand grip, so that the child can support himself. In this form (Fig. 5, *a*), the apparatus permits a flexion exercise,—the child continues to grasp the connecting spokes with the toes and propels the turbine. When the wheel is placed horizontal to the plate and the foot rest is lowered (Fig. 5, *b*), the child can practise adduction. In order to encourage the child, a small animal on wheels is attached to the turbine and, by turning the turbine, the child also moves the animal which can be weighted so as to increase the work done.

INTERNAL SPLINTING OF FRACTURES OF THE FIFTH METACARPAL

BY DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

The usual result of fracture of the head of the fifth (or other) metacarpal is unfortunate both in its roentgenographic and clinical aspects. Rarely is extension of the distal short fragment maintained. Generally union occurs in marked flexion and the prominence of the knuckle is lost. Because of the flexion, a defect persists in extension of the metacarpophalangeal joint. It is true that well-applied and well-maintained extension will generally prevent this, but it does not always do so, and it disables the patient as regards the use of the hand for three weeks and frequently longer.

Recently the pathologist at Sea View Hospital had the misfortune to suffer a fracture of the fifth metacarpal. (See Figure 1.) In this case it was necessary to devise a better, simpler, and less handicapping method of treatment than had been used in the past, and the idea of splinting the distal fragment of the fifth to the fourth metacarpal occurred to the author.

FIG. 1

Under strict asepsis and with the use of the fluoroscope, the writer manipulated the fracture into the best position obtainable (it was three weeks old), and then guided his assistant in drilling two wires at angles through the distal fragment of the fifth metacarpal into the fourth metacarpal. When these wires had been placed, the fracture was perfectly immobilized and the patient was able to move all fingers of this hand without restraint or difficulty.

The wires were clipped off a quarter of an inch outside the skin and a dressing, wrung out of Dakin's solution, was placed around and over them and strapped in place with adhesive. This

FIG. 2-A

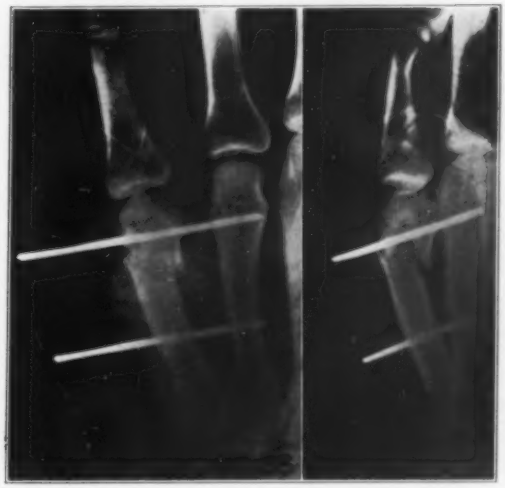


FIG. 2-B

small dressing was left in place for three weeks and then it and the pins were removed. Both pins were found very tightly set in the bone at that time, no absorption having taken place around them. The prominence of the knuckle was well maintained. This patient had meanwhile been able to continue with his full duties as pathologist without pain or loss of the use of any of his fingers.

FIG. 3

In a second case (Figs. 2-A and 2-B) the pins were placed differently. One was drilled through the proximal fragment to hold it forward and the other through the distal fragment to force it backward. Stability in this case was not nearly as good and the distal fragment rotated on the wire, so that the prominence of the knuckle was not as well maintained.

Several other cases have since been treated by the first method with uniformly successful results.

UNUSUAL HALLUX-VARUS DEFORMITY AND ITS SURGICAL CORRECTION

Case Report

BY M. THOMAS HORWITZ, M.D., PHILADELPHIA, PENNSYLVANIA

From the Hospital for Joint Diseases, New York, N. Y.*

J. H., a colored female, aged six, was admitted to the Hospital for Joint Diseases because of congenital deformities of both feet, that of the left disturbing her gait and inhibiting her from wearing a shoe with comfort, unless of special design.

On examination, the right foot presented syndactylism of the first and second and of the third and fourth toes, and a mild hallux varus of 10 degrees. The left foot demonstrated syndactylism of the third and fourth toes, absence of the second toe, and a severe, incorrigible first-metatarsal hallux varus of 45 degrees. (See Figure 1.)

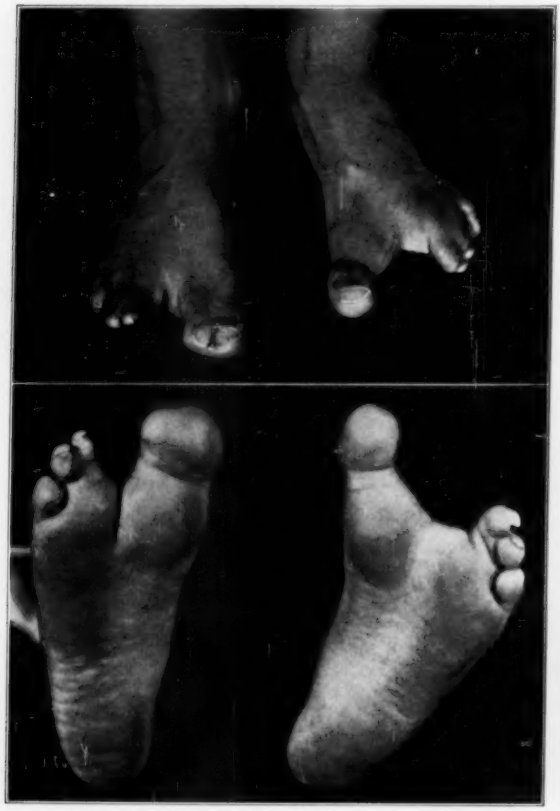


Fig. 1

Feet before operation.

Fig. 2

Left foot six months after operation.

* Service of S. A. Jahss, M.D.

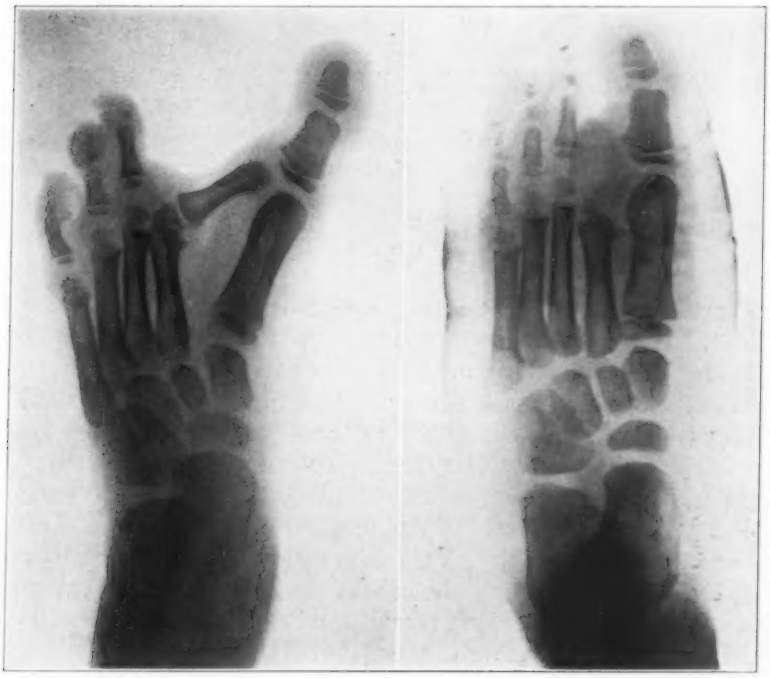


FIG. 3-A FIG. 3-B

Roentgenograms of the left foot.

Fig. 3-A: Before operation.
Fig. 3-B: After operation.

A roentgenogram of the left foot (Fig. 3-A) revealed the proximal phalanx of the second toe in a marked varus position and articulating with the epiphyseal end of the proximal phalanx of the first toe.

The following operative procedure was evolved and performed by Dr. S. A. Jahss, to correct the hallux-varus deformity of the left foot. Interference with the other congenital anomalies present was not considered indicated at this time.

A diamond-shaped portion of skin was removed from between the first and third toes, to avoid excessive redundancy, its base at the web and the apices on the dorsal and plantar surfaces, one and one-half inches from the web margin. The phalanx, articulating between the second metatarsal head and the base of the proximal phalanx of the first toe, was removed. The first and second metatarsals could now be easily approximated, but, since the varus deformity tended to recur, a strip of fascia lata was removed from the right thigh, looped through a drill hole in the first metatarsal head and about the shaft of the second metatarsal, and sutured to itself with the toe held in the corrected position. The deep tissues were closed with interrupted chromic catgut and the skin with black silk, and the correction was reenforced by a compression bandage.

The wound healed by primary union and the patient was discharged wearing ordinary shoes comfortably and without a corrective appliance. Excellent correction has been secured and has been maintained six months postoperatively (Figs. 2 and 3-B).

TREATMENT OF FRACTURES OF THE CLAVICLE

A Special Stand to Facilitate the Reduction and Application of Cast *

BY RUTH JACKSON, M.D., DALLAS, TEXAS

Chief of Orthopaedic Staff, Parkland Hospital, Dallas

Fractures of the clavicle can usually be reduced by the ordinary methods, but the maintenance of the reduction until some form of apparatus for immobilization can be applied has been our greatest problem. The stand shown in Figure 1-A was designed to facilitate reduction of these fractures and the application of a shoulder spica. It is thirty-seven inches high and has a "shoulder seat" and head rest which are adjustable, so that the stand can be used with a table of almost any height. The shoulder seat is a solid strip of metal, thirteen inches long and one and three-fourths inches wide, with the edges slightly beveled to prevent injuring the skin. Three and one-half inches of the shoulder seat project beyond the center of the stand toward the head rest, and the head rest is seven inches from the center of the stand.

As shown in Figure 1-B, the patient's pelvis and lower extremities remain on the table and the stand is placed beneath the upper part of the

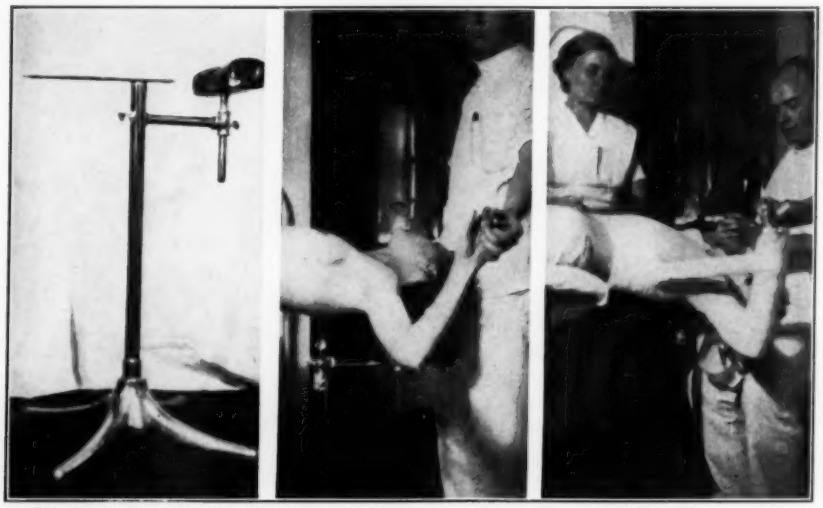


FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: Clavicle stand. The shoulder seat and head rest are adjustable.
Fig. 1-B: Patient ready for reduction.
Fig. 1-C: After reduction and application of cast.

* Presented at the Meeting of the Clinical Orthopedic Society, Dallas, Texas, November 6, 1936.

body, so that the shoulder seat is between the shoulders and the head lies upon the head rest. An assistant holds the arms until a local or general anaesthetic is given. Then the arms are abducted to 80 or 90 degrees and allowed to drop backward as far posterior to the posterior plane of the body as possible, the elbows are flexed, and the assistant maintains this position by holding gently the tips of the patient's fingers. The upper part of the body is easily balanced on the stand by keeping both arms in this position. The weight of the arms pulls the shoulders backward, upward, and outward, and thus maintains constant traction in the long axis of the clavicle.

The surgeon can then very easily manipulate the fragments into position and apply a plaster-of-Paris shoulder spica without in any way altering the position of the fragments. (See Figure 1-C.) When the plaster has set, the stand can be removed by slipping it backward, thus removing the shoulder seat from beneath the cast. The patient is then placed on the table. When the cast is dry, the patient is allowed to be ambulatory. The cast is worn for three or four weeks.

In forty cases of fracture of the outer three-fourths of the clavicle, treated at Parkland Hospital, we have had 100 per cent. excellent reductions, while previously the residents and internes were reducing only about 25 per cent. of such fractures. We feel, therefore, that this stand is very practical in the treatment of fractures of the clavicle. We have also found it useful in treating acromioclavicular dislocations, and for applying any shoulder spica.

A PNEUMATIC TOURNIQUET

BY W. C. CAMPBELL, M.D., MEMPHIS, TENNESSEE, AND H. B. BOYD, M.D., LOS ANGELES, CALIFORNIA

Much damage is often observed after the application of the tourniquets in common use for securing hemostasis in surgery of the extremities. This is apparent from the frequent occurrence of persistent neuritis and tourniquet paralysis which may last for a considerable length of time and, occasionally, may result in permanent damage of nerves and blood vessels. This is most common in the upper extremity.

Therefore, over a period of ten years, one of the authors has experimented with various types of pneumatic tourniquets in an effort to devise an apparatus by means of which pressure could be evenly applied over a large area and the exact amount of pressure could be determined. We have at last secured an instrument which meets these requirements and which will soon be on the market.

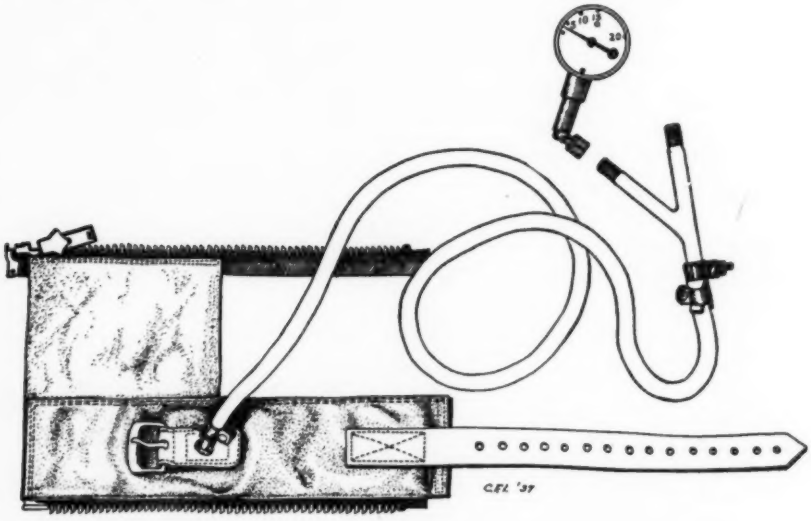


FIG. 1

In constructing this apparatus, an inner tube from a bicycle balloon tire (two and one-fourth inches in diameter) is used. A section, of the proper length to go around the extremity and to overlap two or three inches, is cut. The ends are vulcanized and an ordinary automobile valve stem is inserted in the middle on the convex surface. The valve core is removed from this valve stem. One end of a section of pressure tubing, three feet long, is then slipped over the end of the valve stem and the connection is made air-tight. To the other end of the pressure tubing a Y-shaped valve stem is attached. Valve stems are placed in each open-

ing at the top of the Y. To one of the legs of the Y a pump is attached to inflate the tourniquet. The other outlet is used for testing the pressure. Thus the tourniquet may be inflated as an inner tube, and the pressure may be tested without removing the pump. A bicycle or automobile pump may be used to inflate the tourniquet.

The inner tube described is incased in a complete soft-leather casing. A buckle is attached near the valve stem and a strap is fastened to the opposite end of the casing. We found that, when the tourniquet was inflated, the ends slipped out from beneath the overlapping portion of the casing, allowing the inner tube to expand and to release the pressure. A second flap was then added to the casing to cover the overlapping portion and the strap. This was sewed to one side of the casing and fastened to the other side by means of a zipper which is detachable at both ends.

The amount of pressure required depends upon the size of the individual extremity. For an average-sized adult, fifteen pounds of pressure for the thigh and ten pounds of pressure for the upper extremity are the maximum. The pressure for children is proportionately lower.

A pneumatic tourniquet should not be used unless the exact amount of pressure can be measured. For testing the pressure, we have employed a football gage to which an adapter for testing automobile inner tubes has been attached. This gage is used because the ordinary automobile gages do not register accurately between five and fifteen pounds of pressure, which is the range needed.

The one disadvantage of this pneumatic tourniquet is the expense of having three different lengths of tourniquets to fit various sizes of extremities. This is important, as the tourniquet must fit properly and the tube should overlap two inches or more in order to function satisfactorily.

This pneumatic tourniquet has the following advantages:

1. Pressure is applied evenly over a large area, and the exact amount of pressure is known. This may be the means of preventing tourniquet paralysis.

2. It is easily applied and may be deflated at any time without disturbing the operator or the sterile surgical drapes. This often saves valuable time during the course of an operation.

A "SPICA BOARD" OR BOX

BY F. J. COTTON, M.D., BOSTON, MASSACHUSETTS

Many times in the past the author has felt the need of a really transportable apparatus for use in applying plaster spicas in cases where no Hawley table was available. Therefore, some ten years ago, he devised the spica board shown in the accompanying drawing. It has seen much service and has proved so useful that the author feels it may be of value to others.

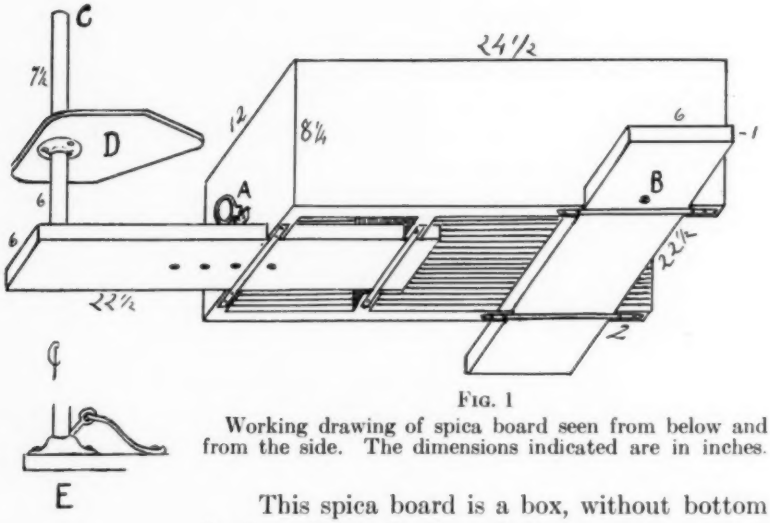


FIG. 1

Working drawing of spica board seen from below and from the side. The dimensions indicated are in inches.

This spica board is a box, without bottom or back, and is made of wood, three-quarters of an inch thick, with slots cut in the end in which the two boards slide. These boards are held in place in the slots by thin metal strips. The longitudinal board is prevented from slipping by a small spring catch, or barrel lock, at *A*, on the front face; the board is held at the desired length by dropping the key down through the appropriate hole. A similar catch on one side drops into the hole, *B*, and holds the cross-board which prevents sidewise tipping. The upright, *C*, is of brass tubing, one inch in diameter. The lower section is screwed into a threaded socket and is kept from rotating by a removable pin, set in through thread and socket. This pin is secured against mislaying by a small leather strap as shown in the inset, *E*. This lower portion, a six-inch post, carries the sacral support, *D*. The upper part, seven and one-half inches long, is removable, screws into a socket just like that on the lower side of *D*, and acts as a perineal support.

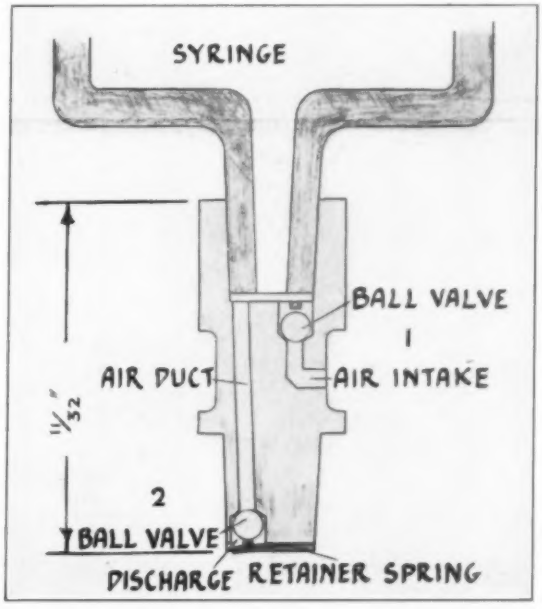
This board was designed so that all the parts, when disjointed, will fit into the main box, and the proportions are such that the apparatus can be carried in an automobile and also placed under a pullman berth. Its construction is simple and can be duplicated by any good mechanic.

A NEW AUTOMATIC VALVE FOR MEASURING AIR INSUFFLATIONS

BY CHARLES MURRAY GRATZ, M.D., NEW YORK, N. Y.

From the Department of Surgery, Division of Orthopaedics, and the Department of Mechanical Engineering, Columbia University, New York

Air has been used for many years for diagnostic and therapeutic purposes in the treatment of pathology involving the lungs and the central nervous system. It also has a small but definite rôle in aiding the surgeon in localizing pathology in the various joints of the human body and the fascial planes. If oxygen is used, it is quite easily measured as it leaves the container, but, if atmospheric air is employed, the armamentarium for injecting and measuring it is rather scanty. If the ordinary syringe is used, its capacity is rarely sufficient for the injection of the desired amount of air without disconnecting the needle. A variable amount of air is inevitably lost when the syringe is removed for refilling. This may interfere with the accuracy of placing the needle and, in addition, the amount of air lost diminishes the accuracy of the procedure.



An automatic valve has been devised which fits a standard Luer syringe and also the standard size of needles. The accompanying illustration shows the details of construction. On the up stroke of the syringe, valve *1* opens and valve *2* closes. Air enters the syringe through the intake and the syringe is filled and the air measured. On the down stroke of the syringe, valve *1* closes and valve *2* opens. This permits the air to be injected through the needle. These valves convert the syringe into a self-measuring pump.

It was very difficult to design an automatic valve of such small dimensions as the one herewith presented. All of the mechanical features were designed by G. B. Karelitz, Professor of Mechanical Engineering, Columbia University, and by Mr. V. I. Zelov. These minute valves of stainless steel should be cleaned with benzine before sterilization and tested each time before being used clinically. They have been found to simplify as well as add to the accuracy of surgical procedures where insufflation is indicated.

A BRACE FOR ARTHRITIC HIP JOINTS

BY DON KING, M.D., F.A.C.S., SAN FRANCISCO, CALIFORNIA

Department of Surgery, Division of Orthopaedics, Stanford University Medical School

One is often surprised at the range of flexion retained by a hip joint, the seat of an advanced degenerative arthritis (malum coxae senilis). Usually there is a fixed external rotation present and any attempt to rotate the thigh causes pain. Close questioning of the patient frequently elicits the information that the hip is more painful when walking on an uneven surface,—*i.e.*, when there is a tendency for rotation to occur.

Hohmann has suggested that a brace, which permits flexion but prevents rotation, will often relieve the pain from which such old people suffer.

During the past two years the writer has used this brace on twelve patients and has found it so satisfactory that he feels justified in reporting it here. Three of these patients have been relieved of pain completely; five others report marked improvement; one feels that there has been slight improvement; and the remaining three have had no improvement whatever.

BRACE CONSTRUCTION

The pelvic belt is a half oval of 18-gage flexible steel, one inch wide. A short upright with a hinge or joint attached is riveted to the belt. Attached to the flexion joint is an upright bar of tempered steel, one-half by five-eighths of an inch, which is curved anteriorly across the thigh, about four inches above the patella. The vertical upright bar is fastened

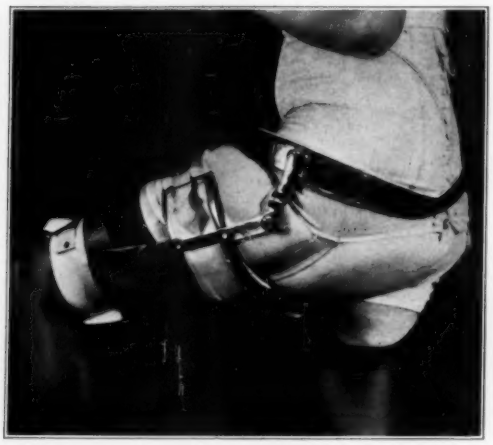


FIG. 1

Side view. Brace applied.

FIG. 2

Front view.

to the thigh by means of two 22-gage duraluminum pelotes, three to three and one-half inches long and seven to eight inches wide. The upper pelote grips the thigh laterally and is fastened to the bar by a swivel rivet. The fixation is done by a single strap of webbing, one and one-half inches wide, encircling the thigh and fastening to a buckle anteriorly.

FIG. 3
Front view.

FIG. 4
Inner aspect of brace.

The lower pelote closes the circle begun by the curved portion of the upright bar about four inches above the patella, and extends around the posterior aspect to the outside of the thigh, where it is fastened to the upright bar by another webbing strap.

The apparatus is finished by felt pads, one-quarter of an inch thick, sewed onto a firm leather backing and riveted to the belt and the pelotes.

A shoulder strap (not shown in the illustrations) over the opposite shoulder helps to carry the belt in position and keeps the brace from slipping.

REFERENCE

HOHMANN: Eine neue Bandage für die chronisch-deformierende Gelenkentzündung des Hüftgelenks. Münchener Med. Wchnschr., LXXIX, 49, 1932.

A BRACE FOR THE CORRECTION OF SPASTIC PRONATION CONTRACTURE OF THE FOREARM

BY MICHAEL S. BURMAN, M.D., NEW YORK, N. Y.

From the Hospital for Joint Diseases, New York, N. Y.*

The purpose of this brace is the gradual passive correction of pronation contracture of the forearm in spastic paralysis.

It consists of an upper-arm piece which is fitted to the anterior aspect of the arm. The upper-arm piece articulates with the upper-forearm piece at a point which is placed on a level with the epicondyles of the elbow joint. Flexion and extension are allowed at the elbow joint, but are controlled by a set screw. An elevated shoulder, acting as a guide in rotation for the forearm piece, is riveted to the upper-forearm piece on its anterior aspect and is placed at the level of the head of the radius when the brace is applied. The forearm piece fits smoothly against the shoulder of the upper-forearm piece, rotates along it, and is maintained in position by a slotted strip of metal which is screwed to the shoulder. A set screw, which moves in the slot, fixes the amount of rotation. The hand piece is riveted to the forearm piece. The thumb is maintained in abduction by a thumb-piece attachment which is well padded, since it is a point of pressure. The hand piece holds the wrist dorsiflexed. It is open dorsally for easier application of the apparatus. The

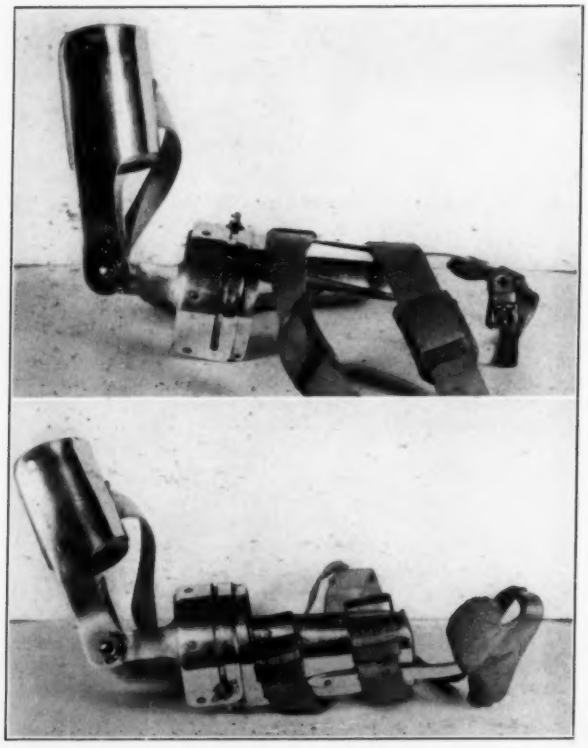


FIG. 1

The lower picture shows the position of the apparatus in pronation. The forearm piece is rotated and fixed in supination in the upper photograph.

*Service of Leo Mayer, M.D.

hand is kept in position by a dorsal strap.

The brace passes above the upper radio-ulnar joint and below the lower radio-ulnar joint, so that it controls the two joints entering into pronation and supination. It includes the hand and exerts thereby a stronger leverage effect. This leverage effect is increased if the elbow is maintained at 90 degrees of flexion by the set screw. The thumb piece keeps the thumb out of the palm. A pressure sore can develop over the thenar eminence if too great a pressure is used at first.

It is not necessary that full supination be reached. All that is needed is accomplished by midposition or a position in supination just a little beyond it.

The author wishes to acknowledge the assistance in making this brace of the late Mr. Otto Feineis and Mr. Alvin Laubender, formerly connected with the Brace Department of the Hospital for Joint Diseases.

FIG. 2

The brace has been disassembled and its component parts are shown.

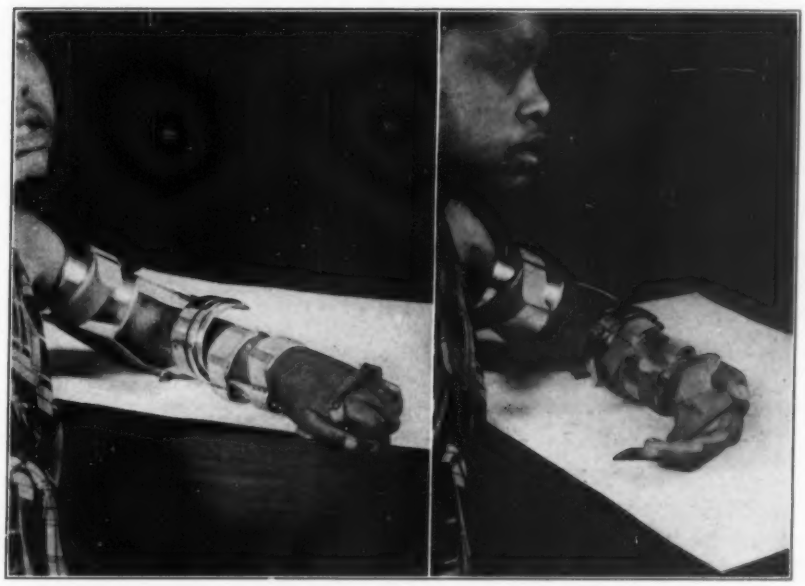


FIG. 3

This shows the brace applied to the arm. In the view on the left, the brace is in the position of pronation; in that on the right, the forearm has been supinated.

A PORTABLE FRAME FOR THE APPLICATION OF HIP AND SHOULDER SPICAS AND CALOT JACKETS

BY ROBERT MAZET, JR., M.D., MANHASSET, LONG ISLAND, NEW YORK

The frame shown in Figures 1 and 2 is an adaptation of the De Croquet frame and Dr. E. H. Oppenheimer's shoulder rest.

It consists primarily of the De Croquet frame. The shoulder rest is made of two rectangular sheets of 13-gage steel, fifteen by eight inches, set eight inches apart on a steel rod, seven-sixteenths of an inch in diameter. The sacral rest consists of a similar sheet of steel as a base on which a pipe,

FIG. 1

FIG. 2

one-half an inch in diameter, supports the seat eight inches from the table. The sacral rest and perineal bar are detachable. The bases of the two rests are connected by a sliding rod to permit adjustments for length of the torso.

For the application of a shoulder spica the position of the patient on the frame is reversed,—the pelvis is supported by what was the shoulder rest, and the shoulders by the back rest which fits onto the upright that formerly supported the sacral seat.

The back rest (Fig. 3) consists of a piece of 13-gage steel, twenty-nine and one-half by three inches, curved to fit the cervical spine and occiput. This conformation to the anatomy is a considerable aid in keeping the patient from slipping off sideways. Beneath the neck curve, six inches

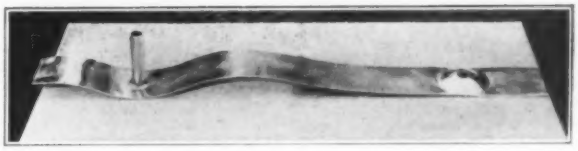


FIG. 3

from the end of the rest, a piece of pipe, seven-sixteenths of an inch in diameter, fits over the rod that supported the sacral seat of the De Croquet frame. Five inches from the other end of the back support is a beveled doughnut, five-eighths of an inch high with a hole, one-half an inch in diameter, in its center. When the back rest is in position, its lower end rests on the pelvic support and its upper end on the other base. This support is withdrawn from above after application of the plaster. It may be used with a Hawley table.

The frame is nickel plated, and weighs twenty pounds; it should have been made of a lighter alloy.

To use the frame for applying a Calot jacket, the back support is reversed and the doughnut is placed on the cephalad upright. The head and neck hang over the end of the back rest and must be supported by a Barton bandage or a Sayre sling. After the plaster dries, the back support is withdrawn from below.

This frame may also be used to apply figure-of-eight bandages for fracture of the clavicle.

INTERNAL-ROTATION BRACE FOR FEMUR

BY HENRY MILCH, M.D., F.A.C.S., NEW YORK, N. Y.

Associate Attending Orthopaedist, Hospital for Joint Diseases, New York City*

In a recent article on the treatment of epiphyseal coxa anteverta [1], it was suggested that the simple Thomas walking hip brace is unsatisfactory, since it cannot prevent external rotation of the leg, which is the essential requirement in treating the disease. In an effort to surmount this difficulty, a pelvic band with a simple hip joint was added to the brace. This seemed to improve the appliance, but did not constantly and completely maintain the desired position of internal rotation. To avoid the necessity for constant readjustment, it seemed desirable to append a short leg piece to the opposite leg, to act as the fixed point against which internal rotation of the affected leg could be accomplished through the pelvic band.

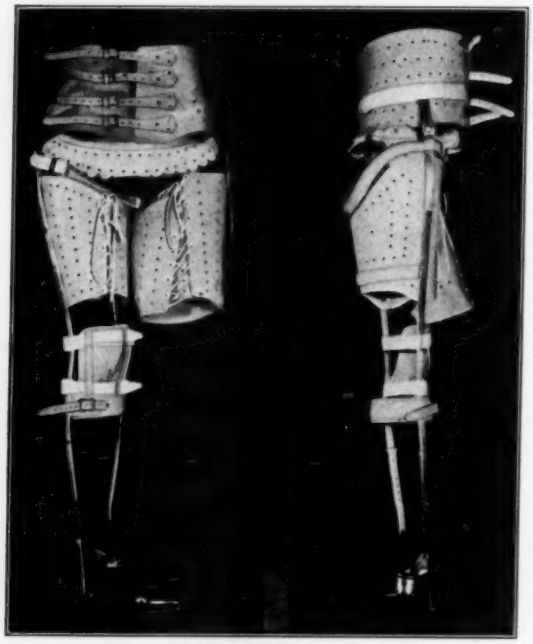


FIG. 1

Front and lateral views of brace without knee joint on affected side, and with simple hinge joint on well side.

Such a brace is shown in Figure 1. It consists of a walking caliper portion for application to the well leg. Where expense is of no moment, a knee joint may be supplied. The leg part is fixed to the pelvic band by means of a simple joint, which permits only flexion and extension. Internal rotation is accomplished by twisting the portion about the hip joint. To the well leg a short thigh piece is added and this is fitted with a simple or a universal joint. This brace is at present being used with complete satisfaction.

1. MILCH, HENRY: Epiphysiolysis or Epiphyseal Coxa Anteverta. J. Bone and Joint Surg., XIX, 97, Jan. 1937.

* Service of Harry Finkelstein, M.D.

ACUTE NEISSERIAN INTRAPELVIC PROTRUSION OF THE ACETABULUM (OTTO PELVIS)

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We wish to present a series of observations on a case of acute intrapelvic protrusion of the acetabulum of Neisserian origin. The period of study covered an entire year and the pathological process was roentgenographically and clinically observed from onset to termination.

CASE REPORT

A. D., white female, aged eighteen, employed as a domestic, was admitted to the New York City Hospital in October 1935 with a low-grade fever and a swollen right knee and hip. The pain was severe and unrelieved by salicylates. There was a history of vaginal discharge for the past two months with bilateral abdominal tenderness and adnexal pelvic masses.

While in the Hospital the patient's temperature varied from 103 to 106 degrees over a three-month period, and she was acutely ill. The urine contained albumin and casts. The sedimentation time was twenty-five minutes.

The blood count was as follows:

Red blood cells	3,200,000
Hemoglobin	50 per cent.
White blood cells	8,500
Polymorphonuclear neutrophiles	78 per cent.
Transitional cells	7 per cent.
Lymphocytes	15 per cent.

The Wassermann and Kahn tests were both negative. Cervical and urethral smears were positive for gonococci, and the complement-fixation test was positive on three different occasions. Roentgenograms of the chest were negative.

The patient was seen in consultation as an orthopaedic problem and placed in traction. During this period the acute intrapelvic protrusion developed, in spite of the traction and non-weight-bearing.

Our roentgenologist, Dr. George J. Plehn, reported on November 12, 1935, that examination of the right hip (Fig. 1) revealed a diminution of density, suggesting marked atrophy of the head and part of the femoral neck, although the contour of the acetabular rim was intact. Nine days later, in spite of continuous hip traction, roentgenographic examination (Fig. 2) showed that there was a pathological process involving the right hip, in which the femoral head showed some destruction. There were productive changes about the floor of the acetabulum, extending into the pelvic cavity in the region of the ischial spine. The head of the right femur seemed to be deeper in the acetabular cavity than normally. This marked the beginning of the formation of an Otto pelvis. The femoral head, in spite of its partial destruction, was pushing the acetabular floor medially into the pelvis.

Traction apparently was incapable of controlling the acuteness of the process or even of making the patient comfortable. Accordingly, on December 2, 1935, she was placed in a plaster spica which included the right hip and extended to the toes. The hip was placed in a position of flexion and abduction. The spica was kept on for four months.

* Service of Lyman W. Crossman, M.D.

FIG. 1

Roentgenogram, taken on November 12, 1935, showing the acute process at its height. Note the marked atrophy of the head and neck of the femur. The joint margins are indistinct, due to effusion into the hip joint.

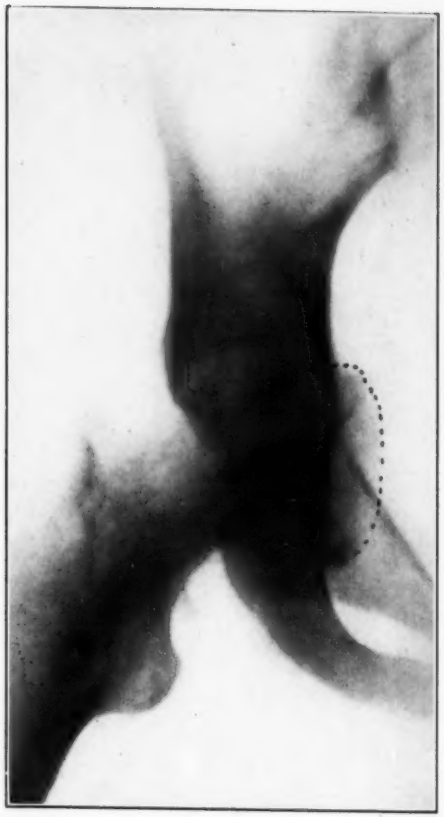

FIG. 2

November 21, 1935, nine days later than Fig. 1. Development of an Otto pelvis has begun. The pelvic floor protrudes medially as shown by the dotted line. The greater trochanter is still far removed from the ilium.

FIG. 3

October 1936, eleven months later than Fig. 1. The arrow marks the definite bulging Otto pelvis. The greater trochanter impinges upon the ilium.

During this period, roentgenograms showed increasing protrusion of the head and, finally, signs of joint fusion.

The cast was removed and diathermy begun on April 10, 1936. On May 22, 1936, the roentgenographic report was as follows: "The head of the right femur has been jammed into the acetabular cavity, so that only a thin rim of bone separates the head from the pelvic cavity. The head is partially destroyed and appears to be ankylosed as a result of the destruction about the right acetabulum."

Examination of the patient, prior to discharge from the Hospital in June 1936, revealed the following: "Patient walks with crutches. As she stands, her right hip and knee are in flexion and her foot is in equinus. This is due to the fact that her right hip is firmly ankylosed in 45 degrees of flexion, 30 degrees of abduction, and 45 degrees of external rotation. The knee flexion and the equinus of the foot are purely compensatory, so that she may touch the ground on walking. Motion of the right knee shows flexion to an angle of 95 degrees and extension to 165 degrees. All pain, swelling, and fever have disappeared."

The patient was readmitted for further study in October 1936. The status of the hip was unchanged. The slight limitation of motion in the right knee had completely disappeared. She walked surprisingly well and could attend to her daily duties. The only thing that bothered her was the cosmetic effect of the externally rotated position of the right foot. We did not believe a corrective osteotomy was indicated at this stage, so she was referred to our Clinic for further observation. Roentgenograms (Fig. 3), taken at this time, showed a definite Otto pelvis. The floor of the acetabulum bulged medially. The head of the femur showed slight destruction and was fused to the acetabulum in which it was deeply embedded. The greater trochanter almost touched the ilium. The lesser trochanter was very prominent, indicating marked external rotation. There was apparent foreshortening of the femoral neck because of this external rotation.

DISCUSSION

Intrapelvic protrusion of the acetabulum is today regarded as a disease process rather than a distinct clinical entity. Any pathological process which weakens the floor of the acetabulum and allows the head of the femur to progress inwardly is capable of producing this deformity. Two main groups are recognized: (1) the acute, rapidly destructive, infectious type; and (2) the slowly progressive, chronic type which occurs during the course of any disease that weakens the acetabular floor. Our case definitely comes under the acute infectious group. Many of these acute infectious hip joints go on to complete ankylosis. Why an Otto pelvis developed in our case before ankylosis occurred is somewhat of a question. It is quite probable that the acuteness of the process so rapidly weakened the acetabular floor that the head of the femur progressed inwardly before ankylosis took place. A comparison of Figures 1 and 2, which were taken only nine days apart, illustrates the great rapidity of the process.

We have been able to locate and tabulate 106 cases in the literature to date. Of this number, only thirteen were assumed, or proved, to be of Neisserian origin. This accounts for only 12 per cent. of the reported cases. We may safely ascribe our case to Neisserian origin, because the patient had a profuse leukorrhoea and adnexal masses, the complement-fixation test was positive, and the cervical smears were positive at the very onset of the joint symptoms.

SUMMARY

A series of observations, covering a period of an entire year, were made in a case of acute Otto pelvis in a girl of eighteen. Roentgenograms demonstrated the onset and rapid development of the acetabular protrusion. Pathological data pointed to a Neisserian origin. The process subsided when ankylosis ensued.

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WAY-SUNG NEW

1892–1937

With regret, *The Journal* announces the death, on May 4, 1937, of Dr. Way-Sung New, of Shanghai, China, where he had established himself in a prominent and important position in the short time during which his health permitted him to carry on the task which he had set for himself. For several years Dr. New was Foreign Editor of *The Journal* in China and was a most valuable means of contact with that country.

Dr. New was born on June 14, 1892. He was a graduate of St. John's University, Shanghai, and of Harvard Medical School. In addition to his connection with other hospitals, he served an interneship on the Orthopaedic Service of the Massachusetts General Hospital.

He returned to China with the purpose of establishing orthopaedic surgery in Shanghai. It was always his ambition to take to his country the teachings and the methods which he had followed in the United States. He established an orthopaedic hospital, supported and conducted by the people of China (the first of its kind in his country), which has been in active operation for about twenty years and has done pioneer work in the care of crippled children, as well as in the treatment of bone and joint diseases. In addition, Dr. New took a very active part in the development of his specialty in China, in affairs of general medical and surgical interest, and in giving opportunity to the surgeons in his country. He served as President of the China Medical Society, and held the position of Professor of Orthopaedic Surgery in the St. John's University Medical School and in the Women's Medical College in Shanghai. His loss will be keenly felt by the profession and by his community.

JOSEPH ISOLIN MITCHELL

1895–1937

On April 7, 1937, Joseph I. Mitchell died after a brief illness, at the age of forty-one. Dr. Mitchell received his premedical and medical education in Memphis, obtaining the degree of Doctor of Medicine from the University of Tennessee Medical School in 1919. He served a Fellowship in Orthopaedic Surgery at The Mayo Clinic from 1919 to 1923, subsequently receiving the degree of Master of Science from the University of Minnesota in 1924. Thereafter, until his untimely death, Dr. Mitchell was associated with the Willis C. Campbell Clinic, of Memphis, Tennessee. He was an Associate Professor of Orthopaedic Surgery at the University of Tennessee. On the attending staff of several Memphis hospitals, and head of the Orthopaedic Service of the John Gaston Hospital, Dr. Mitchell worked well and industriously.

As an active member of many medical societies, including the American Orthopaedic Association, the American Academy of Orthopaedic Surgeons, and the Clinical Orthopedic Society, Dr. Mitchell's contributions to his specialty were numerous and valuable. He published articles on many subjects, including anterior poliomyelitis, scoliosis, knee-joint surgery, acute osteomyelitis, correction of old traumatic deformities, and surgical treatment of affections of the lumbosacral and sacro-iliac joints.

To those who were fortunate in knowing him well, his death means the loss of a modest, sincere friend whose knowledge and judgment were greatly valued. Although rather reticent about expressing opinions, he was an unusually clear thinker and wise counsellor when consulted. In his death Orthopaedic Surgery has suffered a distinct loss.

News Notes

The Fifty-First Annual Meeting of the **American Orthopaedic Association,** which commemorated fifty full years of the existence of the Association, was held in Lincoln and Omaha, Nebraska, on June 2, 3, and 4, 1937, under the presidency of Dr. H. Winnett Orr. Special preparations were made by the President to make this Golden Anniversary of particular interest to the members and guests. Four foreign guests were present: Mr. R. Watson Jones, Liverpool; Dr. Svante Orell, Stockholm; Dr. Alberto Inclán, Havana; and Dr. Lelio Zeno, Rosario.

A particularly interesting program was arranged by the Program Committee. The list of papers which were presented will be found on page 543 of the April issue of *The Journal.* In addition, papers were presented by Dr. Zeno and Dr. Inclán.

At noon on June 3, the members were received by Governor Roy L. Cochran at the Capitol, where they were given an opportunity to inspect this unusual building.

The Annual Banquet was held on June 3 at the Cornhusker Hotel in Lincoln. At this dinner Dr. Orr gave his President's Address on "The Contribution of Orthopaedic Surgery to the Lister Antiseptic Method" and Dr. Robert B. Osgood gave a very comprehensive review of "The History of Orthopaedic Surgery and the American Orthopaedic Association".

On the third day, the members were taken to Omaha where a special clinical program had been arranged at the University Hospital by Dr. John P. Lord, Dr. Herman F. Johnson, and Dr. Robert D. Schrock.

The officers for 1937–1938 are as follows:

President: Frederick C. Kidner, M.D., Detroit, Michigan.
President-Elect: William Ward Plummer, M.D., Buffalo, New York.
Vice-President: Lloyd T. Brown, M.D., Boston, Massachusetts.
Treasurer: John L. Porter, M.D., Evanston, Illinois.
Secretary: Ralph K. Ghormley, M.D., Rochester, Minnesota.

The following Members of Committees and Delegates were elected:

Member of Membership Committee: A. R. Shands, Jr., M.D., Durham, North Carolina.
Member of Program Committee: William B. Carrell, M.D., Dallas, Texas.
Delegates to the American Board of Orthopaedic Surgery: Philip D. Wilson, M.D., New York, N. Y., and Frank R. Ober, M.D., Boston, Massachusetts.
Delegate to the American College of Surgeons: Wallace H. Cole, M.D., St. Paul, Minnesota.
Delegate to the Congress of American Physicians and Surgeons: J. Torrance Rugh, M.D., Philadelphia, Pennsylvania.

The following orthopaedic surgeons were elected to membership in the Association:

Joseph S. Barr, M.D., Boston, Massachusetts.
Robert E. Burns, M.D., Madison, Wisconsin.
Halford Hallock, M.D., New York, N. Y.
John R. Moore, M.D., Philadelphia, Pennsylvania.
Allen F. Voshell, M.D., Baltimore, Maryland.

The following foreign surgeons were elected as Corresponding Members:

Dr. François Petrus Fouché, Johannesburg, South Africa.
Dr. Dimitrije Yovtchitch, Belgrade, Jugoslavia.

Dr. Walter Truslow announces the removal of his office to the Medical Arts Building, 142 Joralemon Street, Brooklyn, New York.

The Sixty-Sixth Annual Meeting of the **American Public Health Association** will take place in New York City on October 5 to 8, 1937. Dr. Reginald M. Atwater is the Executive Secretary of the Association and the headquarters are at 50 West 50th Street, New York, N. Y.

The Twelfth Congress of the **Deutsche Gesellschaft für Unfallheilkunde, Versicherungs- und Versorgungsmedizin** will take place in Würzburg on September 24 and 25, under the presidency of Prof. Dr. Reichardt. A number of valuable papers bearing on this department of surgery will be presented and special attention will be given to the rôle of psychopathology.

Under the patronage of Her Majesty Queen Mary, the Seventh **English-Speaking Conference on Maternity and Child Welfare** was held in the Great Hall, British Medical Association House, Tavistock Square, London, on June 1, 2, and 3, 1937. The Rt. Hon. Sir Kingsley Wood, P.C., M.P. presided. As stated on the program, the theme of the Conference was: "The further evolution of the maternity and child-welfare movement throughout the British Empire and in the United States of America." Visits were also made to a number of maternity and child-welfare institutions.

The **Deutsche Orthopädische Gesellschaft** will hold its next Congress in Rostock on August 27, 28, and 29, under the presidency of Prof. Dr. Friedrich Scheel. The principal subjects to be discussed are: "The Relation of Orthopaedic Surgery to the Physical Development and the Military Efficiency of the German People" and "Diseases and Injuries in the Region of the Shoulder Girdle". These subjects will be discussed by men of prominence from different parts of Germany. There will be the usual social activities for the members and guests.

The **Internationaler Kongress für Kurzwellen in Physik, Biologie und Medizin** will be held in Vienna from July 12 to 17, under the patronage of Dr. A. d'Arsonval, His Excellency the Marquis G. Marconi, and Prof. Dr. J. Zenneck. Among the subjects to be discussed, the following are of orthopaedic interest: "Ultra-Short-Wave Therapy in the Treatment of Acute Infectious Diseases, Especially in the Treatment of Acute Poliomyelitis", and "Short-Wave Diathermy, Its Employment in Chronic Rheumatic Diseases of the Joints and the Muscles". Further information may be secured from the Secretary, Alserstrasse 4, Vienna, IX, Austria.

The next examination of the **American Board of Orthopaedic Surgery** will be held in Los Angeles on January 14 and 15, 1938, just preceding the meeting of the American Academy of Orthopaedic Surgeons. Applications must be in the Secretary's hands at least three months before the date of this examination.

The examination fee has been increased to $50.00, to correspond with that of the other specialty boards, this change of fee to take effect as of October 1, 1937. Applications received prior to October 1 will be considered on the present fee basis,—namely, $25.00.

At the meeting in Atlantic City on June 7 and 8, certificates were granted to 104 candidates.

The annual International Symposium of Rheumatology, organized by the **Ligue Française contre le Rhumatisme,** will be held in Paris on October 9, 1937, under the presidency of Prof. Laignel-Lavastine. The clinical meeting will be held in the morning at Prof. Loeper's Clinic at the Hôpital Saint-Antoine. The afternoon will be devoted to the presentation and discussion of the following papers: "Radio-Active Treatment", by Dr. Coste, of Paris; "Emanotherapy", by Dr. Piery, Dr. Cluzet, and Dr. Milhaud, of Lyons; and "Radio-Active Effects Exerted by Thermal Waters", by Dr. Euziere and Dr. Castagne, of Montpellier. Requests for further information should be addressed to: Permanence de la Journée du Rhumatisme, 23, rue du Cherche-Midi, Paris.

The Fifth Annual Meeting of the **Western Orthopedic Association** will be held in Seattle on July 28, 29, and 30, with headquarters at the Washington Athletic Club. Officers are: Dr. Roger Anderson, Seattle, President; Dr. Vernon Thompson, Los Angeles, Secretary; Dr. Fraser Macpherson, San Diego, Treasurer. Dr. Sylvan L. Haas of San Francisco is President-Elect.

Dry clinics will be given on Wednesday morning, July 28, at the Children's Orthopedic Hospital under the supervision of Dr. H. J. Wyckoff and in the afternoon at the Harborview County Hospital under Dr. Donald Murray. The sessions on Thursday and Friday will include symposia on treatment of fractures of the hip, treatment of fractures of the spine, diagnosis and treatment of shoulder conditions, and treatment of the various types of foot disabilities. Operative clinics on Saturday morning, conducted by the Seattle doctors, will be under the direction of Dr. John LeCocq at the Orthopedic Hospital, and under Dr. Minor Lile at the Harborview Hospital.

In answer to the wide-spread demand for an agency which will attempt to certify competent surgeons, the **American Board of Surgery** was organized on January 9, 1937. This Board is a member of the Advisory Board of Medical Specialties which includes all of the boards of certification for the different medical specialties which have been already organized. Acting upon the invitation of the American Surgical Association, the following surgical societies cooperated in the creation of the American Board of Surgery: the American Surgical Association, the Surgical Section of the American Medical Association, the American College of Surgeons, the Southern Surgical Association, the Western Surgical Association, the Pacific Coast Surgical Association, and the New England Surgical Society. Two groups of candidates are recognized for qualification by the Board: (1) those who have already amply demonstrated their fitness as trained specialists in surgery; (2) those who, having met the general and special requirements exacted by the Board, successfully pass its qualifying examination. All applications for the first group (the Founders' Group) must be received within two years of the Board's organization. The Board will hold its first examination on September 20, 1937. Requests for information and application blanks should be addressed to the Secretary, Dr. J. Stewart Rodman, 225 South 15th Street, Philadelphia, Pennsylvania.

At recent Executive Committee Meetings of the **British Orthopaedic Association,** the following have been elected to membership:

Full Member

Mr. Arthur M. Connell, 18 Taptonville Crescent, Sheffield 10.

Associate Members

Mr. A. L. Eyre Brooke, Wingfield Morris Orthopaedic Hospital, Headington, Oxford.
Mr. W. S. Diggle, Walton Hospital, Liverpool.
Mr. W. A. Elliston, Children's Hospital, Longwood Avenue, Boston, Massachusetts, U. S. A.
Mr. D. Evans, 41 Newfoundland Road, Cardiff, Wales.
Dr. R. S. Garden, Northern Hospital, Liverpool 3.
Mr. W. Gissane, St. James's Hospital, London, S.W. 12.
Mr. T. V. Ley, Wagga Wagga, N. S. W., Australia.
Miss E. McComas, 29 Mary Street, Hawthorn, E 2, Victoria, Australia.
Mr. D. D. Pinnock, 57a Wimpole Street, London, W. 1.
Mr. J. W. M. Sutherland, 99 Clifton Road, Aberdeen, Scotland.
Mr. C. S. Walker, 17 Woodland Avenue, Wolstanton, Stoke-on-Trent.
Mr. J. Y. C. Yieh, Lester Chinese Hospital, Shantung Road, Shanghai, China.

Honorary Member

Dr. Paul Guildal, Orthopaedic Hospital, Copenhagen, Denmark.

Current Literature

A Manual of Radiological Diagnosis for Students and General Practitioners. Ivan C. C. Tchaperoff, M.A., M.D., D.M.R.E. (Camb.). With a Foreword by Philip H. Mitchiner, M.D., M.S., F.R.C.S. Baltimore, William Wood & Co., 1937. $6.00.

As indicated in the foreword by Mr. Mitchiner, this book furnishes a standard of comparison for the benefit of those desirous of observing such evidences of bone and soft-part pathology as are capable of being visualized by roentgenographic examination. After emphasizing in the introduction the absolute necessity for coordination of clinical studies with roentgenographic findings, if one is to arrive at a "reasoned reading" of a roentgenogram, the author proceeds, in Chapter I, to a brief technical consideration of what roentgenograms are, how they are generated, and what their effects are,—namely, fluorescent, photographic, and biological.

In Chapter II is taken up a general consideration of bones and joints: first, and briefly, from the normal standpoint; and, second, from a pathological standpoint. In these sections, as in the regional divisions of the subject, the reproductions, direct from the negatives, are well-nigh perfect, bringing out the pathology of the various lesions as they have not been shown in any text with which the reviewer is familiar. The descriptive text is no less illuminating than the pictures themselves.

In the regional section (Chapters III to VIII) a very complete presentation of the diseases common to the different anatomical divisions of the body, so far as they lend themselves to roentgenographic study, is set forth with an entirely adequate discussion. This includes the skull, the teeth, the spine, and all the rest of the osseous skeleton, the contents of the thoracic and abdominal cavities, the genito-urinary tract, the gall-bladder, the female generative organs and the foetus, and, finally, tumors of the spinal cord and ventriculography.

The whole work, beautifully done by the publishers and carrying an excellent index, is the most helpful guide to an understanding of x-ray pathology that has yet been presented.

Traité de chirurgie orthopédique. L. Ombrédanne et P. Mathieu. (En 5 Volumes.) Paris, Masson et Cie, 1937. Chaque tome, 300 francs; les 5 volumes, 1,500 francs.

This is an exhaustive work in five volumes, the first two of which have already appeared. In these volumes the two Directors have had the collaboration of sixty-one surgeons, chosen for their special training and experience in the subjects assigned to them. This treatise is essentially an exposition of the position of this department of surgery and of the work accomplished by the French orthopaedic surgeons, but the contributions and opinions of workers and investigators in other countries are fully recognized and accredited. Although the subjects are essentially orthopaedic, traumatology has been given a recognized position and its intimate relation and interwoven interests with orthopaedic surgery have received due prominence.

The scope of the subjects is planned to cover completely the field of orthopaedic surgery, with a full consideration of each topic and a presentation of the information which has resulted from recent investigations by those who are qualified for such special work.

Volume I presents the general physiology, pathology, and therapeutics of the component structures, especially of the bones, joints, muscles, tendons, and skin. Volume II deals with the nervous system and also includes the treatment of the sequelae of many of these diseases, particularly of the deformities resulting from infantile paralysis. Affections of the blood are next considered, followed by a discussion of the roentgenographic diagnosis in the treatment of sequelae of trauma. The second part of this volume is devoted to the spine and the upper extremity, and includes a discussion of the three

regions of the spine, with the affections found associated with them. This regional consideration is continued through the third, fourth, and part of the fifth volumes. Each portion of the body is considered, both as to the structures of the different parts and the conditions which are usually associated with them. The discussion of the generalities which precedes the pathology, clinical features, and treatment of each subject produces the impression of thoroughness and comprehensiveness.

It is seldom that we have a work so comprehensive in its scope with the details of each portion of the subject so accurately treated by those who are eminently fitted to give the most recent information. The reader is able to inform himself in a practical way on any phase of orthopaedic surgery, which would ordinarily be possible only by laborious consultation of an extensive amount of literature. The accurate subdivision into the related subjects leads the student to understand by what methods he should further conduct his investigation, and it also gives a good illustration of the interrelation of many of the subjects included in the constantly increasing scope of this specialty.

The two volumes already issued give indication of what may be expected from the following three. The books are beautifully bound and the quality of the printing is excellent. The illustrations are numerous, well selected, and of the same excellent quality which has always characterized the publications of Masson et Cie.

CHIRURGIE UND RECHT. DIE HAFTUNG DES CHIRURGEN UND DIE SICHERUNGSMASSNAHMEN IN DER PRAXIS. (Surgery and Law. The Liability of the Surgeon and Safeguards in His Practice.) Dr. med. Richard Goldhahn und Dr. jur. Werner Hartmann. Stuttgart, Ferdinand Enke, 1937. 11.80 marks.

To aid the surgeon in avoiding the pitfalls which land him in the courts of law, the authors have compiled a readable little manual of "do's" and "don'ts". They have explained the surgeon's responsibility in each phase of his practice and have abstracted many illustrative cases to emphasize the following important points: consent to operation, explanation of the nature of the operation, and the dangers connected with the operation itself. The loss of foreign bodies naturally occupies considerable space. The dangers connected with general and local anaesthesia, injections, and blood transfusion are outlined. There are chapters on conservative treatment and the omission or overdose of x-ray. The legal aspects of the surgeon's liability are briefly summarized in an appendix.

Presented as a timely warning, the book will probably be consulted more by those who are already in trouble. The principles involved are international, although the cases are from the German courts. There is a place for the volume in any medical library.

HANDBOOK OF ORTHOPAEDIC SURGERY. Alfred Rives Shands, Jr., B.A., M.D. In Collaboration with Richard Beverly Raney, B.A., M.D. St. Louis, The C. V. Mosby Co., 1937. $5.00.

The purpose of this handbook, as stated in the preface, is "to present for the consideration of the medical student and the general practitioner the fundamental facts and principles of orthopaedic surgery as concisely as possible and yet in sufficient detail to convey a well-rounded knowledge of the subject".

It is obvious that in a text of 500 pages it would be impossible to cover in detail the multitude of therapeutic measures that are used for orthopaedic disabilities. The diagnostic points and clinical pathology of practically all the more important orthopaedic disabilities are discussed in a concise and clear fashion. The illustrations are diagrammatic sketches and are to be commended for their simplicity and the clarity with which they convey the ideas intended by the author.

The specialist in orthopaedic surgery will probably find the book of little use, but for the medical student and the general practitioner it fulfills the need for that groundwork of information upon which they can build a more adequate knowledge of any particular disease process by reference to the bibliography.

TUMOR UND UNFALL (Tumor and Injury). Erich Fenster. (Vorträge aus der praktischen Chirurgie, 14. Heft.) Stuttgart, Ferdinand Enke, 1937. 2.40 marks.

This booklet of thirty-two pages discusses the causal relationship between tumor formation and trauma as it occurs in medicolegal cases. One phase includes the injuries which are attributable more to a preexisting malignancy than to the factor of external trauma, as in spontaneous fractures.

In some instances, trauma has been shown to cause tumor formation in animals and in man. A predisposition to tumor formation must be assumed. The predisposition favors the presence of a germinal unit of tumor which occurs through an embryonic or degenerative disturbance of development; both may be either hereditary or acquired. In estimating the external factor which stimulates further tumor growth, it is important to establish a latent period (which in man is usually a matter of years), a certain continuity of "bridge" symptoms which characterize this latent period, and a coincidence between tumor site and point of outspoken injury.

Certain types of tumors may be more easily attributed to the influence of trauma than others, when degree and time relationship of the injury are sufficiently evident.

In attempting to determine a causal relationship between trauma and malignant tumor formation, histological proof of the nature of the tumor should be required. Roentgenograms should be taken at the time of injury, particularly in cases where bone is involved, with repetition over a period of time during which the indications given by the roentgenogram are important.

The final opinion in such medicolegal cases should be based on precise determination of fact and given by an arbiter who possesses the advantages of medical experience and the knowledge of pathology.

ELEMENTS OF ORTHOPAEDIC SURGERY. N. Ross Smith, M.B., Ch.M. (Sydney), F.R.C.S. (Eng.). Foreword by R. C. Elmslie, O.B.E., M.S., F.R.C.S. Baltimore, William Wood & Co., 1937. $4.00.

This is a useful book of nearly 250 pages, well illustrated, and well written. Its "aim . . . is to present a concise and practical account of the elements of orthopaedic surgery for practitioners and students . . . and for nurses and masseurs engaged in orthopaedic work." The purpose is good, but its accomplishment is well-nigh impossible to fulfill completely, because both the knowledge and the duties of its desired audience vary so greatly. Certain chapters—such as those dealing with the organization of welfare work for cripples (education, occupation, psychology), postural deformity, miscellaneous bone and joint disease, neoplasms, and fractures—are to be warmly commended. In the opinion of the reviewer, less praise can be given to certain of the other chapters dealing with specific defects, lesions, or diseases,—such as congenital deformities and rheumatic diseases. There seem to be fairly important omissions also,—for example, the extreme importance of early diagnosis of congenital dislocation of the hip by which all trauma commonly caused by manipulation may be avoided by the simple abduction treatment. Except for one sentence in the Appendix on Physiotherapy, the proved value of tank or pool treatment during the convalescent stage of poliomyelitis receives no mention. The very common lesions of the bursae, such as the subacromial or prepatellar, are not discussed.

Mr. R. C. Elmslie, the eminent orthopaedic surgeon of London, writes a preword to the volume, and there are three appendices. The author's diction is as admirable as is the publishers' make-up.

A BRIEF OUTLINE OF MODERN TREATMENT OF FRACTURES. H. Waldo Spiers, A.B., M.D. Ed. 2. Baltimore, William Wood & Co., 1937. $2.00.

This book of 133 pages attempts to illustrate the fundamentals of fracture surgery and to touch the high spots of treatment. It is important that this be done for the benefit of the undergraduate medical student and for the interne.

In general, the book is well written. Its very existence is significant of the tremendously increasing importance of the subject of fractures and dislocations. It is also significant that the author maintains the distinction between the subjects of orthopaedic surgery and the surgery of fractures. The book will be helpful to beginners in surgery.

TECHNIQUE OF UNDERWATER GYMNASTICS. A STUDY IN PRACTICAL APPLICATION. Charles Leroy Lowman, M.D., F.A.C.S., Susan G. Roen, Ruth Aust, B.S., and Helen G. Paull, B.S. Los Angeles, American Publications, Inc., 1937. $5.00.

The authors state that the purpose of the book is to assist those concerned with the practical application of corrective and therapeutic exercises in water.

Dr. Lowman and his associates present carefully studied and detailed information for building, locating, and maintaining the physical equipment of pools. The care required for properly locating pools is emphasized and its importance shown. The necessity for prevention of infection is stressed and methods for correction are described. The authors go into considerable detail in regard to the chemical study of the water used, but this is needed for the sake of completeness.

An important feature of the book is the description of charts for recording disabilities and their follow-up. The illustrations of treatment methods are excellent and the outline of the types of disease amenable to pool treatment is helpful.

The book should be of great value to anyone concerned with the supervision of distillation of a pool and is of importance to anyone directing pool activities.

DIE ATEMBEWEGUNGEN DER NORM UND FEHLFORM (Normal and Abnormal Respiratory Movement). Rudolf Dittrich. (Beilageheft zur Zeitschrift für Orthopädie, Bd. 65.) Stuttgart, Ferdinand Enke, 1937. 15 marks.

This book is a detailed study and presentation of the mechanics of respiration, based on the structures involved in the act of breathing and on a geometrical analysis of the part which each plays in this act. Although it is correlated with body metabolism and circulation, respiration is seen to be governed by physical laws.

The first section of the book is devoted to the variety of respiratory movements found in the normal individual—young and old, singer and athlete—with an explanation of the need for coordinate and rhythmic breathing to secure efficiency in bodily activity. Synergism between respiration and circulation is emphasized. Careful description is accorded prolonged exertion and the various phases of respiration which are initiated by the "warming-up" period.

In the second section, Dittrich gives a physiological basis to the school of psychotherapy which successfully treats a number of psychic disorders by regulation of breathing. Analysis and treatment of abnormal respiratory movements are given for cases of deformity of the thoracic cage and of the vertebral column. An example of Dittrich's detailed analysis is found in his explanation of the frequent association with scoliosis of nasal obstruction, high palate, and mouth-breathing.

The last portion of the book deals with the technique of methods of examination, including x-ray kymography and x-ray cinematography.

"Atembewegungen der Norm und Fehlform" is a new and thorough contribution to the physiology of respiration and a valuable reference book in this field.

LIBRE JUBILAIRE OFFERT AU DOCTEUR ALBIN LAMBOTTE PAR SES AMIS ET SES ÉLÈVES. Brussels, Vromant & Co., 1936.

This volume of over 500 pages, profusely illustrated, was completed by the friends and former students of Dr. Lambotte. The list of collaborators constitutes a short catalogue of well-known orthopaedic surgeons throughout the world. The contributions consist mainly of short summaries of the work of each surgeon, printed in his native tongue. Taken all in all, they present an excellent and concise statement of the main osteosynthetic procedures at present employed throughout the world. Dedicated as

they are to the father, or the arch proponent, of the operative treatment of factures, it is but natural that these articles should form an enthusiastic tribute to the method as well as to the man who did most to establish the method. Several interesting addresses by Prof. Hustinx, Prof. Sauerbruch, and Prof. Leriche serve as introductions to the volume. Of these, the last, a discourse on "The Future of Bone Surgery", is a masterful piece of writing. Considering bone surgery from a broad biological point of view, it is a stimulating tribute, laid reverently at the feet of a great master by another great master and friend.

HEALTH AND MUSCULAR HABITS. Lieut.-Colonel J. K. McConnel, D.S.O., M.C., and F. W. W. Griffin, M.A., M.D. London, J. & A. Churchill Ltd., 1937. 5 shillings.

The authors, with a competent understanding of kinesiology, have put into non-technical phraseology an explanation of the mechanics of movement in the activities of daily life. No attempt has been made to consider deformities or cases needing medical care. It is the aim of the book to make the individual aware of the mechanics involved in normal motions and to recognize and to correct faulty movements, thereby forming new and correct habits.

Balance of the pelvis, reciprocal muscle action, breathing, tasks of the abdominal, back, and pectoral muscles, and the feet are given consideration. Following each chapter explaining the working of the various parts is a section devoted to an analysis of faulty use and instruction in methods of correction. One can readily recognize in the descriptions of poor mechanics the insidious habits which, becoming fixed, cause poor posture, and one can realize how ineffectual exercise periods and special exercises will be unless these habits are corrected.

This book can be recommended to doctors and physiotherapists as a workable volume, and to the individual who wishes to become mechanically efficient as within his scope and appealing to his intelligence.

DIABETES UND CHIRURGIE. A. W. Fischer. (Vorträge aus der praktischen Chirurgie, 12. Heft.) Stuttgart, Ferdinand Enke, 1937.

In this booklet of twenty-eight pages are discussed briefly the surgical problems presented by the diabetic patient. The author emphasizes the facts that some manifestations of latent and active diabetic coma may be confused with symptoms of peritonitis, and the regression of leukocytosis under antidiabetic treatment in the presence of glycosuria differentiates the condition from a true peritonitis in which a leukocytosis is uninfluenced by antidiabetic treatment.

Surgery in a diabetic is absolutely contra-indicated by a blood sugar of 350 milligrams per 100 cubic centimeters and a carbon dioxide combining power of less than 40 volumes per cent. Improvement of such a condition by insulin, glucose, and, if necessary, a 5-per-cent. solution of sodium bicarbonate given intravenously permits operation within two to three hours. Where operation is not urgent, at least a week should be given to preoperative preparation, with sufficient carbohydrate to restore depleted glycogen.

In the matter of accident insurance, it is necessary to determine that diabetes and not merely an initiating injury is the determining cause of the consequences.

The surgical treatment of localized infections and gangrene attributable to diabetes is well discussed. The author advocates radical methods aided by evipan and electrosurgery.

SURGICAL TREATMENT. A PRACTICAL TREATISE ON THE THERAPY OF SURGICAL DISEASES. James Peter Warbasse, M.D., F.A.C.S., and Calvin Mason Smyth, Jr., B.S., M.D., F.A.C.S. 3 Vols. Ed. 2. Philadelphia and London, W. B. Saunders Co., 1937. $35.00.

There have been a number of single volumes or systems of surgery during the past few years and this second edition of a three-volume set devoted to surgical treatment does not necessarily add a great deal to the sum total of accessible knowledge of the subject. The manner of the classification and arrangement of the sections leaves much to

be desired. From the standpoint of the specialist, the plan would not be at all desirable, and the general surgeon or physician might find it inconvenient also. This text is written primarily for the physician in general practice or the general surgeon, and the arrangement may be more satisfactory from their standpoint. The material is made more readily accessible by the inclusion of a separate Index volume.

This second edition represents a revision of each section. Most significant changes are those in the chapters on blood transfusion and the management of the syphilitic patient, and there is a marked enlargement of the chapter on physical therapy such as light, heat, electricity, x-ray, and radium. Fracture treatment has been considered primarily from the standpoint of fundamental principles and, while some of the newer methods and the apparatus recommended for their execution have been described, the authors have selected at least one method which they themselves prefer and have given this in detail so that any doctor who possesses the mechanical natural skill essential for the successful management of fractures can carry it out.

The text is simple, concise, easy to read, and well illustrated with anatomical drawings. In the Foreword the authors state that "Surgery is an art based upon a complex of sciences". For this reason they have suggested various procedures as a stimulus to the originality of the reader. Throughout the three volumes many of the illustrations have been simplified in the form of diagrammatic line drawings which help to make clear the surgical principles and procedures described.

Sections of the book dealing with first aid to the injured, bandaging, and minor surgery should be especially welcome to the doctor in general practice whose problems have to be dealt with in his own office.

These three volumes could be recommended as a text for students and as a source of reference for the general surgeon. The set is as complete, accurate, and up to date as any work of a similar nature published in the English language.

The Journal wishes to acknowledge the receipt of the following publications sent to the Editorial Department:

*Die Anatomie der angebornenen Hüftverrenkung. V. Putti. Stuttgart, Ferdinand Enke, 1937.

*Fracturas y Luxaciones. Terencio Gioia. Tomo II. Buenos Aires, Aniceto Lopez, 1934.

*Short-Wave Diathermy. Tibor de Cholnoky. New York, Columbia University Press, 1937.

*La spondylolyse et ses conséquences. Spondylolisthésis; scoliose listhésique. P. Glorieux et C. Roederer. Paris, Masson et C^ie^, 1937.

Anales del Servicio de Traumatología, Cirugía Ortopédica y Accidentes del Trabajo del Hospital Provincial de Valencia, III, Núms, 31–36, 1936.

Bethesda (Pittsburgh, Penna.), XXXIX, No. 2, 1937.

Bollettino e Atti Reale Accademia Medica di Roma, LXII, Fasc. 7–10, 1936.

Bulletin of the National Tuberculosis Association, XXIII, Nos. 4, 5, and 6, 1937.

The Bulletin of Westchester County Division Podiatry Society of the State of New York, March, April, and May, 1937.

Central Council for the Care of Cripples (National Council for Maternity & Child-Welfare). Report for the Year 1936. London, 1936.

The Child (Washington, D. C.), I, Nos. 9, 10, 11, and 12, 1937.

Cleveland Clinic Quarterly, IV, No. 2, 1937.

Die Entwicklungsstörungen der menschlichen Gliedmassen. Fehler im Bereich der Gliedmassen bei sog. systemisierten Missbildungen des Bewegungsapparates. 7. Die multiple angeborene Gelenkstarre. 8. Pleonosteosis familiaris (Léri). B. Valentin. Jena, Gustav Fischer, 1937.

Journal de Médecine de Bordeaux et du Sud-Ouest, CXIV, Nos. 8–9, 1937.

Radiography and Clinical Photography, XIII, No. 1, 1937.

*To be reviewed in a subsequent issue.

Roche Review, I, Nos. 8 and 9, 1937.

The Rotarian, L, No. 6, 1937.

"Solvitur Ambulando." A Symposium on Prosthetic Achievement. London, J. E. Hanger & Co. Ltd., 1937.

University of Pennsylvania Bulletin. Graduate School of Medicine, Announcement for Session 1937–1938. Philadelphia, 1937.

KURZER ÜBERBLICK ÜBER PATHOLOGIE UND KLINIK DER BIZEPSSEHNENRUPTUREN NEBST EINIGEN EIGENEN FÄLLEN (A Brief Summary of the Pathology and Clinical Findings in Rupture of Biceps Tendon with Case Reports). Torsten Björkroth. *Acta Chirurgica Scandinavica*, LXXIX, 280, 1937.

Because of its intra-articular course, the long head of the biceps is predisposed to rupture as a result of arthritic and periarthritic changes in the shoulder joint. Six cases of this lesion are reported in detail with two cases each of rupture of the short head and of the common tendon of the biceps. Dislocation of the shoulder predisposes to rupture of the biceps. In old individuals it may be this lesion and not chronic arthritis which causes disability.

Good results were obtained in four cases of rupture of the long head by looping the tendon through a tunnel at the base of the greater tuberosity.—*W. P. Blount, M.D., Milwaukee, Wisconsin.*

STILLSCHE KRANKHEIT UND TUBERCULOSE (Still's Disease and Tuberculosis). Halfdan Sundt. *Acta Orthopaedica Scandinavica*, VII, 205, 1936.

To establish the diagnosis of Still's disease, it is necessary to have at some time during the illness the cardinal symptoms of polyarticular swelling, polyadenitis, and enlargement of the spleen. Remissions may last for several years. Most opinions attribute the disease to chronic infection with staphylococci or streptococci. A few writers think that it may be produced by different arthrotropic viruses, including the tuberculous virus.

Two true cases of Still's disease are reported in detail in which tuberculosis was the probable cause. Both patients were males. In one, the onset was at the age of seven with acute polyarthritis, high fever, and severe pain. Three years later fluid from the right subacromial bursa was proved tuberculous by guinea-pig inoculation, and an excised cervical lymph gland, by histological examination. Post-mortem examination showed extensive tuberculous involvement of lymph glands, peritoneum, pericardium, and pleura, but chronic villous synovitis without gross evidence of tuberculosis. In the other case, the onset was at thirteen months as an acute polyarthritis. When the patient was seen seven years later, there was typical involvement, including symmetrical tenovaginitis of the hands and feet. Injection of tuberculin produced an indisputable focal reaction in the tendon sheaths at both wrists. Extirpated sheaths were negative histologically for tuberculosis.

The writer attributes the characteristic findings in these cases to tuberculous infection and the non-specific changes in the synovial membrane in one and the tendon sheaths in the other to a particular allergic reaction.

He suggests that enlargement of the lymph glands, liver, and spleen may occur to a lesser degree or as a transitory phenomenon in various forms of chronic polyarthritis as a result of some special constitutional condition (lymphism). This particular way of reacting to the infection need not constitute a distinction between Still's disease and other types of chronic polyarthritis of childhood.—*W. P. Blount, M.D., Milwaukee, Wisconsin.*

TREATMENT OF TUBERCULOSIS OF THE ELBOW BY RESECTION AND ARTHROPLASTIC OPERATION IN ONE SEANCE. Ragnar Magnusson. *Acta Orthopaedica Scandinavica*, VII, 325, 1936.

Combined resection and arthroplasty was performed in seventeen cases of tuberculosis of the elbow. Abscesses and fistulae were cleaned up at the time of the operation

and were not considered a contra-indication. The synovia and all tuberculous material were cut away and a piece of fascia lata was inserted. Motion was started in from two to three weeks and resistance exercises soon thereafter. Massage was not given.

Follow-up examinations or questionnaires in sixteen cases showed ankylosis in one and mobility in the remainder. Twelve patients were able to work as maids and seamstresses, and one patient, as a timber floater. All wounds remained healed after the patients left the hospital except for one case in which a fistula formed. Only four patients had occasional pain. The results were better in the cases operated on early in the disease.—*W. P. Blount, M.D., Milwaukee, Wisconsin.*

ZUR KENNTNIS DER MENISKUSGANGLIEN IM KNIEGELENK (Ganglia of the Semilunar Cartilages of the Knee). E. Norinder. *Acta Orthopaedica Scandinavica*, VII, 362, 1936.

Five cases of ganglia of the semilunar cartilages are reported,—four of the lateral cartilage (one bilateral pair), and one of the medial. The diagnosis had been made by palpating the ganglion. The symptoms were relatively slight with no locking. The lesion of the medial cartilage was in connection with a tear and the cartilage was removed. Three of the ganglia of the lateral cartilages were operated upon. The tumors were removed but the cartilages themselves were not disturbed. The symptoms were relieved.—*W. P. Blount, M.D., Milwaukee, Wisconsin.*

CHORDOMA. Van D. Barnes and Seward E. Owen. *The American Journal of Cancer*, XXIX, 541, March 1937.

The authors report a case of sacrococcygeal chordoma in a male patient of fifty-nine, confirmed by biopsy and roentgenogram, in whom x-ray treatment afforded partial symptomatic relief. They have encountered four cases of chordoma in 4000 admissions of males for cancer treatment at the Veterans' Administration Clinic, Hines, Illinois. There is a brief review of the literature and a full report of the case with autopsy findings. Assays of urinary prolan showed a small amount on several occasions, rising at the time of the patient's last visit to 1000 mouse units per liter. No physiological explanation for these findings is offered.—*Grantley W. Taylor, M.D., Boston, Massachusetts.*

OSTEOGENIC SARCOMA OF THE FEMUR IN A GUINEA-PIG. S. A. Leader. *The American Journal of Cancer*, XXIX, 546, March 1937.

The author adds a case of osteogenic sarcoma of the femur to the twenty recorded instances of spontaneous tumors in guinea-pigs. This guinea-pig, of unrecorded ancestry, presented pulmonary metastases. Numerous photographs and two photomicrographs confirm the character of the tumor.—*Grantley W. Taylor, M.D., Boston, Massachusetts.*

OSSIFYING FIBROMA OF THE MAXILLARY SINUS: REPORT OF A CASE SUCCESSFULLY TREATED WITH IRRADIATION. Isidore Arons. *The American Journal of Cancer*, XXIX, 551, March 1937.

The author reports a case of ossifying fibroma of the antrum in an eleven-year-old boy, successfully treated with large doses of radium and x-ray. He emphasizes the benign character of this neoplasm, and accounts for the methods of treatment employed by the fact that the original pathological diagnosis was mistakenly osteogenic sarcoma. He concludes, however, that ossifying fibroma may be successfully treated by radiation alone.

Photographs and roentgenograms illustrate the report. The photograph of the patient ten years after treatment shows some facial asymmetry and a marked radiation change over the entire cheek.—*Grantley W. Taylor, M.D., Boston, Massachusetts.*

PAGET'S DISEASE ASSOCIATED WITH HYPERNEPHROMA. Herman Charache. *The American Journal of Cancer*, XXIX, 729, Apr. 1937.

The author reports with roentgenograms and photomicrographs a case of coincident Paget's disease of the skeleton and hypernephroma with multiple skeletal metastases. The patient was a male, sixty-three years old, whose symptoms were chiefly due to the metastases involving the tibia. Roentgenographic findings disclosed characteristic appearances of both pathological conditions. Autopsy confirmed the clinical diagnoses.—*Grantley W. Taylor, M.D., Boston, Massachusetts.*

MYOSITIS OSSIFICANS. M. H. Hobart. *American Journal of Surgery*, XXXIV, 227, 1936.

The author classifies two types of this condition described as deposition of bone in muscles or about their insertions,—namely, progressive, which usually begins in the muscles along the spine and gradually spreads to all muscles of the body with interference with respiration, and the circumscribed, which is usually confined to one muscle or locality, and, if caused by trauma, may spread more rapidly to reach its maximum degree of involvement.

The theories as to the cause are implantation of periosteum in muscle, or the escape of osteogenic cells from the periosteum, or ossifying hematoma, or metaplasia. It is usually considered that trauma—either mild or severe, in the form of repeated injury, dislocations about a joint, or variations in the treatment of fractures—is a factor in all cases. The more common sites are the brachialis anticus and the quadriceps femoris muscles.

From the pathological standpoint, there is a degeneration of muscle fibers, with infiltration of fibrous tissues, cartilage cells, and normal appearing bone, which may, or may not, be attached to the bone beneath. The usual symptoms are interference with function, less often pain, and a mass in the muscle becoming larger and firmer, with roentgenographic evidence of shadow, usually seen three or four weeks after injury.

Prognosis is generally good except in cases in which a joint is involved; if such cases are neglected or improperly treated, interference with function may result. Early treatment usually consists of rest, preferably in a cast; in the case of the elbow, stress is laid upon the flexion position to prevent the formation of a mass in the cubital fossa. By the time the diagnosis is made, heat is usually indicated either in the form of diathermy or hydrotherapy. Surgical interference is indicated only if pain is continued or if function is interfered with, and, in some instances, in order to differentiate from tumor. Quiescent cases should not be disturbed.

Nine cases are reported in detail.—*Custis Lee Hall, M.D., Washington, D. C.*

GRIDDING THE FEMORAL HEAD AND NECK AREA IN FRACTURE OF NECK OF FEMUR FOR SIMPLER GUIDANCE AND PLACEMENT OF THE SMITH-PETERSEN THREE-FLANGED NAIL. Michael S. Burman. *American Journal of Surgery*, XXXIV, 237, 1936.

The author describes his method of plotting the direction of Kirschner wires for the placement of the Smith-Petersen nail.

After the fracture has been reduced, "a Kirschner wire is placed on the skin in the line of the head and neck of the femur at an eye-estimated angle of 115 degrees to 125 degrees and two parallel wires about one-quarter of an inch apart are placed above the first wire and two below. A field is thereby gridded out which includes the entire head and neck area of the femur." A roentgenogram is then taken, which shows the position of the head and neck of the femur, the fracture, and the trochanter in relation to the wires. In this way the placement of the nail may be determined. With this group of wires as a guide, two wires are placed in the bone parallel to the skin wires. These wires placed in the bone are then identified on the film and the one selected as being best placed is used as a guide for the nail.

This method may prove of help to those who have not as yet worked out and used

their own method or modification of determining the angle and depth of the wire. The advantages of the author's technique are simplicity and lessening of the time necessary in the placement of the wire as a guide.—*Custis Lee Hall, M.D., Washington, D. C.*

OSTEOSCLEROSIS (TRAUMATIC) OF CARPAL BONE. A SUGGESTION AS TO TREATMENT. Lewis Clark Wagner. *American Journal of Surgery*, XXXIV, 357, 1936.

Eight cases of osteosclerosis of the carpal, semilunar, and scaphoid bones are reported and classified as Kienböck's disease. As to the etiology of the condition, two acceptable theories are mentioned: (1) paroxysmal angiospasm, with local ischaemia, followed by local necrosis; and (2) a traumatic axon reflex, described by Leriche, with vasoconstriction and vasodilatation, hyperaemia, and resulting bone absorption. This is a preliminary stage to bone death and vascular obliteration.

There have been reported in the literature a large number of cases of fracture and non-union of the carpal scaphoid in which, following the use of a bone graft, roentgenographic examination showed retrabeculation. The author reports a series of cases, treated by bone grafts and drilling, with roentgenograms indicating regeneration of the trophic and sclerosed bone in the carpal region, absorption of the grafts between the articular surfaces of the reconstructed carpal bones, and marked diminution of symptoms of pain and stiffness, with improved function. Postoperative roentgenograms showed restoration of the normal appearance of the carpal bones.

Several authors have obtained similar results by simply drilling the fragments, allowing revascularization. There is no doubt that drilling alone, or drilling and grafting, gives far better end results than the excision of even small portions of the affected carpal bone, which, as an operative procedure in this type of condition, should be discarded in favor of bone grafting or drilling, or both.—*Custis Lee Hall, M.D., Washington, D. C.*

RUPTURES AND TEARS OF MUSCLES AND TENDONS. H. Earle Conwell and R. H. Alldredge. *American Journal of Surgery*, XXXV, 22, 1937.

Injuries to the muscles and tendons have previously been considered rare, but, undoubtedly, many cases have been overlooked due to incomplete study and examination and the likelihood of diagnosis as sprain or bursitis, when the actual condition is a tearing of muscles and tendons.

From the etiological standpoint, the authors group these injuries according to the classification of Gilcreest, due primarily to senility, pathological changes, physiological predisposition, occupational injuries, fatigue, and trauma.

In the order of frequency, the most common sites of injury are the muscles of the calf, the extensors of the leg, the biceps tendon, and the Achilles tendon. Many of these cases can be treated conservatively if the lesion is not too serious to allow healing to take place, without permanent dysfunction. Operative procedure is indicated in the cases in which gross changes are found. Treatment should consist of immobilization for a period of from two to three weeks in the cases of partial rupture, and for a longer period in the operative cases, depending upon extent and location of the lesion, the healing muscle being placed entirely at rest following operative repair.

The authors report eleven cases. The etiological factors and the diagnostic methods are well described, and the article is illustrated to show the characteristics of the more common varieties. The injuries occur more frequently in middle-aged individuals in whom the weakening of muscles and ligaments, associated with stress and strain, causes the injury. They can best be diagnosed by careful examination, with particular reference to localized pain, loss of function or painful function, or a defect in the muscle or tendon, with or without ecchymosis.—*Custis Lee Hall, M.D., Washington, D. C.*

ORGANIC CALCIUM IN HEALING OF FRACTURES. Greshom Downs. *American Journal of Surgery*, XXXV, 34, 1937.

From an experimental study of the relation of calcium to the healing of fractured fibulae in rats, the author found that the fractures healed more readily when the animals

were on a diet in which protein was present in abundance and in which the calcium and phosphate were present in adequate quantities and proper ratio. An organic calcium phosphate was used in these studies and it is suggested that it was more readily and more completely metabolized than inorganic forms of calcium. However, there was not a great deal of variation noted after the feeding of the two types of organic calcium salt, but that obtained from the cereal, Indian Corn, was utilized more readily by the organism than that from milk. Weight gains of the animals were observed during the course of the experiment and, from the breaking-strength test of the healed fibulae and from the histological studies, more rapid and complete healing was noted. The blood studies were negative except that calciphos caused more rapid clotting of the blood, indicating the value of further work in this direction.—*Custis Lee Hall, M.D., Washington, D. C.*

ACUTE SUPPURATIVE TENOSYNOVITIS OF THE FLEXOR TENDON SHEATHS OF THE HAND. A REVIEW OF ONE HUNDRED AND TWENTY-FIVE CASES. Robert S. Grinnell. *Annals of Surgery*, CV, 97, Jan. 1937.

Infection of the tendon sheath may occur from one of four routes,—puncture wound (primary), extension from a neighboring infection (secondary), blood stream, or lymphatic spread. None of the cases in this series were due to lymphatic or blood-stream infection, except seven gonococcus infections which are discussed separately.

There were sixty-seven primary and fifty-eight secondary cases. All gave a history of trauma. In 47 per cent. the wound was near or in the flexor crease. The distal crease alone was involved in forty-one cases. The next most common site was the distal closed space (twenty-three cases). The right hand was involved twice as often as the left, and the digits were affected in the order named: second, third, first, fourth, and fifth.

Early diagnosis is essential. The average delay in operation, because of error in diagnosis, was one day in the primary group and four days or more in the secondary group. Diagnosis is based on tenderness localized to the region of the sheath, flexion deformity in the digit, exquisite tenderness on extension of the distal phalanx, and a wound of entry. In the secondary group, diagnosis is more difficult. Infection outside the sheath confuses the picture, and it is difficult to determine whether or not the sheath has been invaded when a localized portion of the sheath only is involved.

End results, based on a follow-up of sixteen months, were discouraging. Over one-third of all cases fell into Group I (bad) and nearly two-thirds belonged in Groups II and III (fair, good). Only one-sixth of the patients regained approximately full function.

Gross sloughing of the tendons in whole or in part occurred in 52 per cent. of the cases.

The streptococcus hemolyticus was the infecting organism in 36 per cent. of the cases and the staphylococcus in 31 per cent. The remaining cases were not cultured, or mixed infections were found. The results were better in the staphylococcus infections. Tendon slough was about equal in the two types of infection, but much higher in the mixed infection.

The radial bursa was involved thirteen times, the ulna eight times, and both were affected in ten instances. In all but one case the spread was from the radial bursa. In only one case was the digital sheath of the thumb involved without extension to the radial bursa. The thenar space was involved in fifteen cases; the midpalmar, in four; the forearm, in nine; and the wrist joint, in one. Extension from the volar to the dorsal surface occurred ten times. There was one death, and the prognosis was definitely poorer with advancing age. There were three arm and eight finger amputations. Osteomyelitis occurred in 38 per cent. of the cases; the middle phalanx was most often involved.

The average time from operation to complete healing was fifty-three days. Delay before operation and incomplete drainage are probably the most important causes of poor results.

Treatment: Incisions were usually multiple, short, anterolateral, bilateral or uni-

lateral, over the proximal and middle closed digital spaces, and a single midline incision over the sheath in the palm. The latter is recommended whenever the digital sheath is involved. The bursae above the wrist were usually drained by lateral incisions, as advocated by Kanavel. Digital incisions, lateral to anterior vessels, were not used, as interference with sheath and tendon nutrition was feared. Truncated finger flaps, as suggested by Auchincloss, are recommended,—one for the proximal and one for the middle closed spaces. The distal end is cut along the flexion crease and the sides are cut obliquely to avoid the anterior vessels and nerves, including all tissues down to the tendon sheath, and extending nearly to the next proximal crease. This method affords better drainage. Sterile wet dressings of saline or boric solution postoperatively give better results than hot soaks.

In the seven cases of hematogenous gonococcal tenosynovitis, healing occurred in twenty days. There was no sloughing of the tendons, and the results were almost uniformly good.—*N. T. Kirk, M.D., San Francisco, California.*

ADAMANTINOMA OF THE JAW. Robert H. Ivy and Lawrence Curtis. *Annals of Surgery*, CV, 125, Jan. 1937.

Adamantinoma is a tumor derived from the enamel-forming cells of the dental epithelium, usually characterized by multilocular cystic formation, or it may be a solid tissue tumor in its early stages. Calcification or enamel formation, as the name implies, is never seen. The molar region of the mandible is most frequently involved. The cortical bone becomes distended and may become perforated. The cystic cavities are lined with cuboidal cells and filled with viscid, brownish fluid; in the fibrous tissue or bone surrounding them, columnar cells are found, having the histological characteristics of the enamel organ (ameloblasts). The tumor occurs at any age and is not considered malignant, although it tends to recur locally.

It produces a painless swelling, slowly increasing in size in the alveolar process; the outer plate usually shows more involvement than the inner. The tumor is lobulated in form and, when the overlying bone becomes thinned, it feels elastic on pressure. Roentgenograms show the growth divided into compartments by fine bony trebeculae. Occasionally it is impossible before operation to differentiate this tumor from giant-cell tumor, osteitis fibrosa cystica, sarcoma, or metastatic growths. The clinical course of the aberrant dentigerous cyst very closely resembles that of adamantinoma, so that for practical purposes of treatment it is just as well to regard them as one and the same.

Treatment: Complete removal of the abnormal epithelium is essential, or recurrence follows. Enucleation and curettage, when the tumor is small and surrounded by well-defined bony walls, occasionally results in cure. This may be supplemented by radium implantation. Recurrence is not infrequent.

When the tumor is large, extending into surrounding bone or soft parts, complete resection should be the initial treatment followed by bone transplantation.

Sixteen cases are reported, three in detail. In fifteen the mandible was involved and in one the maxilla was affected. Four were treated by conservative enucleation; two, by enucleation and radium; five, by primary resection; and five, by secondary resection for recurrence after enucleation.—*N. T. Kirk, M.D., San Francisco, California.*

UNUNITED FRACTURES OF THE SHAFT OF THE HUMERUS. Willis C. Campbell. *Annals of Surgery*, CV, 135, Jan. 1937.

Fifty cases of non-union are reported, forty-nine of which were treated by massive onlay grafts; bony union was obtained in 93.8 per cent. One long oblique fracture united after fixation by autogenous bone nails.

Delayed union and non-union occur more frequently in the humerus than in any other long bone, due to the fact that complete immobilization by external apparatus is impossible. Of 226 ununited fractures treated by massive grafts, fifty-three were in the

tibia, thirty-two in the femur, fifty-two in the humerus, and eighty-nine in the forearm. In 4000 fresh fractures of shafts of long bones the distribution was: leg, 1066; femur, 758; forearm, 1883; humerus, 293.

Operative technique: All scar and fibrous tissue is removed from the fragment ends, the medulla is reamed out, and just as little periosteum is stripped as is necessary, leaving attached the blood supply. The fragments are flattened with a chisel, and "shavings" are removed for the graft "bed". A broad, flat, massive graft is taken from the opposite tibia, with "sufficient length, breadth, and dimension to secure firm fixation". The graft is split longitudinally with a motor saw into an outer cortical plate and an inner or endosteal plate. A strip of the latter is placed in the medulla and the rest used as chips about the fracture. The outer plate is secured to the flattened humerus by autogenous bone nails driven into four or more drill holes. The bone nails are made from a separate graft, or part of the original outer plate is used. A rotary file, attached to the motor saw, and a metal gage are used to make them. Spongy bone from the head of the tibia is removed by a sharp bone curette and added about the fracture site. A cast is applied from the rib margins, over both shoulders, to the knuckles of the affected arm.

Twelve cases were operated on within four months after the original injury, and there were no failures; thirty-eight cases were operated on after four months with three failures.—*N. T. Kirk, M.D., San Francisco, California.*

THE APPLICATION OF COBRA VENOM IN MODERN MEDICINE. J. Singh Chowhan. *The Antiseptic*, XXXIV, 273, 1937.

The author states that the use of cobra venom is reported to have relieved the pains of sciatica and severe neuralgia. "In specific non-rheumatoid arthritis, . . . there was a strong decrease in the swellings of the joints particularly in the gonorrhoeal and tuberculous processes, together with relief of pain." Fifteen cases of arthrosis of the knee, shoulder, or spine were treated, with marked analgesic effect and considerable subsequent functional improvement.—*Robert M. Green, M.D., Boston, Massachusetts.*

CHONDROMATOSIS OF THE JOINTS. Ernst Freund. *Archives of Surgery*, XXXIV, 670, Apr. 1937.

Freund takes exception to Lexer's theory that chondromatosis of joints represents a tumor growth of the synovial membrane. Instead, he considers this a metaplastic hyperplasia of the connective tissue, with chondral predominance, but also with calcification and bone formation. He believes the condition is analogous to myositis ossificans, even to the similarity in spontaneous resorption when the secondary irritative factors are removed by immobilization. He offers no explanation for the etiology, but describes in full three cases which he has studied.—*I. William Nachlas, M.D., Baltimore, Maryland.*

USE OF HOMOLOGOUS BONE GRAFTS IN CASES OF OSTEOGENESIS IMPERFECTA. Alan DeForest Smith. *Archives of Surgery*, XXXIV, 686, Apr. 1937.

The author reports the correction of deformities in osteogenesis imperfecta by the use of homologous bone grafts.

The grafts in these cases are considered merely scaffoldings for the new bone to grow on so that the fact that they are taken from the parents or from strangers, or even that one of the grafts was placed in a sterile test tube and refrigerated for several weeks prior to the second operation, makes no difference in the use of the grafts.

He reports four cases treated in this manner, with successful results.—*I. William Nachlas, M.D., Baltimore, Maryland.*

REFLEX DYSTROPHY OF THE EXTREMITIES. Géza de Takáts. *Archives of Surgery*, XXXIV, 939, May 1937.

The author calls attention to the reflex dystrophy occasionally seen in extremities which have sustained mild traumata or infections or injuries to the vascular system, and describes five such cases which he has observed. The essential findings in the patients

are: (1) a hard, non-pitting oedema; (2) bone changes, consisting of a spotty atrophy, retarding of growth, and premature closing of the epiphyses; (3) sensory changes, characterized by increased sensitivity to temperature changes and pressure and localized hyperaesthesia; (4) vasomotor disturbances, with a glossy skin, changes of skin temperature, overgrowths of hair, and eczema; (5) muscle hyperirritability or atony; (6) brittle and ribbed nails; and (7) contracted joint capsules, giving painful motion.

The disturbances are produced by a chronic irritation which sends impulses through the sensory nerves to the cord where they are relayed to the lateral horn and stimulate the efferent sympathetic nerves to the extremity. This reflex is accentuated by the removal of cerebral inhibitions as in mentally unstable or defective persons.

The treatment recommended consists of breaking the arc by excision of the irritant or by sympathectomy.—*I. William Nachlas, M.D., Baltimore, Maryland.*

ASEPTISCHE KNOCHENNEKROSE IN DER PATELLA (Aseptic Bone Necrosis in the Patella). Paul Rostock. *Bruns' Beiträge zur klinischen Chirurgie*, CLXIV, 177, 1936.

The author reports a case of aseptic necrosis of bone in the patella of a forty-year-old man, who sustained a slight injury to the knee. Five days after the injury a lateral roentgenogram revealed a longitudinal rarefaction in the lower pole of the patella, extending upward from just above the lower border of the patella. Within this zone of rarefaction lay a very fine, but well-defined, needlelike sequestrum. Three weeks later this focus was removed. Histological section from the sequestrum bed revealed marked hypertrophy of the media and intima of the vessels, with almost complete obliteration of the lumen and definite reactive changes. No bacteria were present. The slight trauma could not have produced these changes within five days.

The author has observed four other similar cases which he previously described as "osteopathia patellae". He finds only three cases in the literature.

The two cases which Gellman has described as osteochondritis dissecans of the patella are "partite patella" according to the author.—*Harold Unger, M.D., Iowa City, Iowa.*

UN CAS DE LA MALADIE DE SVEN JOHANSSON-SINDING LARSEN. Willy Smets. *Bulletin de la Société Belge d'Orthopédie*, VIII, 163, 1936.

This is a name given to an osteochondritis of the lower end of the patella. It seems to the author unfair to make a morbid entity of this condition. The symptoms are not characteristic of simple traumatic lesions which produce a certain roentgenographic picture at the lower end of the patella. It is essentially an abnormal process of osteogenesis at the point of the patella, which may be grouped with the other disturbances of endochondral ossification, such as Köhler's disease, etc.

Clinically, it is characterized by painful phenomena at the point of the lower end of the patella, and it occurs in children between the ages of nine and fourteen. The author also maintains that the roentgenographic changes simply denote a normal stage of the ossification of the patella. One case is reported.—*Arthur Steindler, M.D., Iowa City, Iowa.*

OSTEOMYELITIS AND SUPPURATIVE JOINTS: SALT WATER POOL TREATMENT. A. Brockway. *California and Western Medicine*, XLVI, 174, March 1937.

The author discusses the salt-water-pool treatment of acute suppurative arthritis, acute osteomyelitis with suppuration of the adjacent joint, and osteomyelitis in which the disease closely encroaches upon a joint structure. He reports thirty cases and shows how this treatment facilitates painless joint movement without muscle spasm, a more rapid healing of the infective process, and a better prognosis for permanent motion in the joint.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

ALGUNAS CONSIDERACIONES SOBRE EL TRATAMIENTO DE LAS OSTEOMIELITIS AGUDAS (Some Considerations of the Treatment of Acute Osteomyelitis). Etienne Sorrell. *Cirurgia Ortopédica y Traumatologia*, V, 3, 1937.

The author calls attention to recent publications on the use of antitoxin and staphylococcus serum in the treatment of grave staphylococcic septicaemia and their effect on the prognosis of the disease. He believes that they offer some hope, but that osteomyelitis, in spite of its likeness to grave staphylococcic septicaemia and septic pyaemia with multiple foci, is so different from them in regard to clinical behavior and prognosis that the same therapy cannot be employed indiscriminately.

He holds that localized osteomyelitic foci produce septicaemic foci and secondary foci against which the organism is almost defenseless, as they do not produce the necessary antibodies.

In speaking about the general treatment, the author points out the failure of vaccine therapy and the scanty success of the bacteriophage method. He is convinced that the use of staphylococcus antitoxin and serum is still in the experimental stage, and he cites the good results which he obtained in four hopeless cases by the use of electrocuprol. However, no one of these therapeutic methods precludes the surgical treatment of the lesion. This, of course, varies according to the type of osteomyelitis to be treated.

Four cases are reported, treated as follows: The first, by incision of the periosteum without bone trepanation; the second, which was a little more serious, by simple bone trepanation; the third, even graver than the preceding ones, by a Hallopeau operation,—a resection of the subperiosteal diaphysis; and the fourth, presenting a septicaemic form with few local signs, by arthrotomy and hip drainage, which relieved the pain without changing the septicaemic condition. He compares the evolution of these cases with the probable results of an expectant treatment and arrives at the conclusion that, except in cases of staphylococcic septicaemia with few localized bone symptoms which justify a delay, speedy surgical intervention is indicated, the technique of which depends on the type of lesion present.—*Alberto Inclán, M.D., Havana, Cuba.*

ACUTE HEMATOGENOUS OSTEOMYELITIS IN CHILDREN. Vernon L. Hart. *Journal of the American Medical Association*, CVIII, 524, 1937.

Due to the many types and various stages of osteomyelitis, there is confusion in regard to the proper treatment in the acute stage. This is a local manifestation of a bacteraemia which is itself usually transient. Its first skeletal manifestation is localized in a single metaphysis of a long bone, or in the juxta-epiphyseal region of other bones. It is not in the medullary cavity or in the cortex. Therefore, surgery should be limited to the metaphysis in this stage.

The author presents the anatomy of the condition in a clear manner and the point is brought out that the rupture of the cortex, as the infection extends, takes place in the paper-thin region of the metaphysis adjacent to the epiphyseal line. The infection rarely travels through the avascular epiphyseal disc, and in bones where the epiphyseal line is extracapsular the joints are rarely involved in the infection, for the periosteum is attached at the epiphyseal line. The usual mode of spread is subperiosteal rather than intramedullary and for this reason the medulla should not be disturbed surgically.

The infection remains localized in the metaphysis for several hours to several days. The diagnosis must be made and the operation done within this time to prevent chronic drainage and sequestration. When there is subperiosteal pus, the disease is no longer acute hematogenous osteomyelitis. The name "acute hematogenous metaphysitis" should be added to the terminology, for it describes the phase when surgery may prevent chronicity.

The diagnosis in this stage is not based on swelling, redness, and oedema, for they are not yet present. Point tenderness over the metaphysis is the most important sign. The joint is clinically normal when examined gently and carefully, although there may be limitation of movements. The chief complaint is incessant pain in the neighborhood of the joint. There is intense toxaemia with high temperature and a rapid pulse. The white blood count is as high as 30,000. Roentgenograms in this stage are always negative.

Treatment is divided into two types, depending on whether or not there is cortical rupture. Adequate attention to dehydration and the general condition is a primary

consideration. When the cortex has not been perforated, a small incision to expose just the metaphysis is made and no pus is seen. The periosteum over the region to be decompressed is then elevated, and drill holes, or a window, one-half by one inch, are made in the thin cortex over the point of tenderness. The cancellous bone is not curetted. A culture of the cancellous bone, or pus if it is seen, should be made. The wound is lightly packed with petrolatum gauze and a plaster cast is applied as in the Orr method. This allows drainage without periosteal separation. When cortical rupture takes place, the local symptoms are definitely changed. Swelling, redness, and oedema are then present, and the tenderness and pain are no longer localized to one point as before. In this critical period the treatment has often been too radical, for these children are not good surgical risks. Their general treatment is extremely important. In this stage there is subperiosteal pus, but, as a rule, the medullary cavity is not yet infected. For this reason, the cortex and medulla should not be opened widely. The soft-tissue abscess should be opened widely, however, and the author suggests widening the perforated area in the cortex of the metaphysis. He makes one drill hole into the medulla of the adjacent diaphysis, so that if pus should be present it can escape. This does no harm and may give valuable information. Dressings of the Orr type and a cast are then applied.

Regardless of the treatment, the clinical picture will not dramatically end following this, for there is still a septicaemia. The part should be watched for signs of spreading infection and during this period the general care must continue as before. Any new foci should be treated in the same manner.

The author suggests that in bones where diaphysectomy can be done without sacrificing the function of the part, as in the case of the fibula, such a procedure is indicated. The diaphysis is removed as far as the periosteum has been stripped by the pus.

It is pointed out that in spite of all this treatment many patients will gradually pass into the chronic stage.—*Newton C. Mead, M.D., Dallas, Texas.*

THE EXAMINATION OF THE CEREBRO-SPINAL FLUID. W. E. Carnegie Dickson. *The Medical Press and Circular Supplement*, Symposium No. 1, p. 18, 1937.

This article presents a discussion of the various methods of gaining information through subarachnoid puncture and of the subsequent examination of the fluid obtained.

The author gives a reasonable explanation of the severe headache that often follows lumbar puncture and shows how it may be prevented. He thinks that the headache is due to constant seepage of cerebrospinal fluid from the spine after the needle has been removed and that this seepage may be prevented by a certain method of inserting the needle.

The dura mater is composed of vertically running parallel strands of thickened fibrous tissue in one sheet and it is tense and tight in a vertical direction. If a spinal-puncture needle is inserted with the sharp cutting edge transversely, it will cut one or more of these vertical thickened strands. Since these strands are constantly tense, the needle wound will gap open and allow cerebrospinal fluid to seep out constantly. However, if this needle is inserted so that the cutting edge is vertical, the opening in the dura will be vertical or parallel to the thickened strands. When the needle is withdrawn, the opening closes immediately, due to the tension of the vertical thickened strands of the dura, and seepage of fluid is prevented.—*Herbert E. Hipps, M.D., Marlin, Texas.*

SCHENKELHALSFISSUR MIT SEKUNDÄRER DYSTROPHIE UND ARTHROSIS DEFORMANS (Fracture of the Neck of the Femur with Secondary Dystrophy and Arthrosis Deformans). Paul Sudeck. *Monatsschrift für Unfallheilkunde und Versicherungsmedizin*, XLIV, 249, May 1937.

Following a relatively mild injury that was considered and treated as a contusion of the hip, a man, twenty-three years of age, developed progressive symptoms of pain, atrophy, and circulatory disturbances of the extremity. This was associated with a flexion and abduction contracture of the hip, with limited, painful motion. Roentgenographic studies over a course of two years revealed a marked spotty atrophy of the

bones about the hip, with a deposition of lime salts to give the appearance of an arthrosis deformans. The neck of the femur was found to have been fractured on the posterior aspect and to have healed with callus overgrowth.

Sudeck postulates that, following a relatively mild incomplete fracture of the neck of the femur, there occurred a secondary distrophy and eventually an arthrosis deformans.—*I. William Nachlas, M.D., Baltimore, Maryland.*

NEW AMPUTATION THROUGH FEMUR AT THE KNEE. C. Latimer Callander. *Northwest Medicine*, XXXVI, 49, Feb. 1937.

The author presents a method of low amputation of the thigh through the use of extra long flaps and the severance of the muscles through their tendinous attachments only, a splitting of the tissues along their fascial planes. The weight-bearing end is covered by the patellar fossa of the quadriceps tendon. He reports thirty-nine cases, in most of which the patients were over seventy years of age, with a mortality of only 9 per cent.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

LE TABES POLYARTHROPATHIQUE (Tabetic Polyarthropathy). Henri Roger, Paul Vigne, et A.-Maurice Recordier. *La Presse Médicale*, XLV, 118, 1937.

The authors report the case of a female whom they first saw in 1923 at the age of fifty-eight. At that time the patient had suffered over a period of fifteen years from lightning pains, etc. In 1916 an arthropathy of the left hip developed. This patient manifested typical signs of tabes. In 1933 the right hip was involved and the lumbosacral, the thoracic, and the cervical spines later became involved. Both shoulders showed a typical Charcot destruction. Both knees demonstrated osseous changes. The left elbow presented osteophytes and the hands showed evidence of decalcification.

Attention is called to the fact that, although tabes usually is monarticular, it may equally well be polyarticular.—*Henry Milch, M.D., New York, N. Y.*

ARTHROSES MICRO-POLYTRAUMATIQUES DU COUDE (Microtraumatic Arthroses of the Elbow). J. Belot et L. Nahan. *La Presse Médicale*, XLV, 135, 1937.

A number of interesting roentgenograms are presented, describing the osteo-arthritic lesions which are found in the elbow joints of employees, following the prolonged use of the pneumatic hammer. While the elbow is most frequently afflicted, the wrist or shoulder may also be involved. The condition develops insidiously as a result of prolonged microtraumata. The patients are usually symptom-free, until some trivial accident attracts the attention of the physician to the involved region. The trauma usually elicits mild pain, which apparently disappears while the patient is at work, and which seemingly is not affected by change of temperature. Flexion is moderately interfered with; extension is seldom completely possible. Supination, however, is limited to a much less degree than the extent of the involvement, as demonstrated by the roentgenograms, would lead one to believe.

While the trauma caused by the use of the pneumatic hammer cannot be denied, the fact is that the condition develops in only a small percentage of laborers,—in not over 2 per cent. This raises the question as to whether there may not be an underlying vasomotor imbalance, which may be the fundamental basis upon which the repeated traumata make their appearance.—*Henry Milch, M.D., New York, N. Y.*

L'OSTÉO-ARTHRITE SÈCHE TRAPÉZO-MÉTACARPIENNE (Dry Osteo-Arthritis of the Trapeziometacarpal Joint). Jacques Forestier. *La Presse Médicale*, XLV, 315, 1937.

Forestier calls attention to the fact that the carpometacarpal joint of the thumb is frequently the site of degenerative arthrosis. The condition is more frequently found in women than in men, appears to be most commonly associated with the menopausal period, and makes its appearance between fifty and seventy years of age.

Fifty-seven cases have been seen by the author among 4,000 cases of arthritides of varying etiology. The condition is characterized by diffuse pain felt along the radial border of the hand. It is apparently made worse by movements or efforts at prehension and is not affected by change of weather. Clinically, the onset of the condition is marked by a definite increase in the size of the joint and crepitation, without limitation of motion. Later, limitation of motion, especially of abduction of the thumb, appears, and finally there is an outward and forward dislocation of the base of the proximal phalanx, which explains the prominence noted at the base of the thumb. Pathologically, this condition would seem to be due to a degenerative form of arthritis, and is to be grouped in the class of osteo-arthroses. Roentgenographically, the condition is characterized by narrowing of the joint interspace, the development of osteophytes on the trapezium, and, ultimately, outward dislocation on the base of the phalanx.

The condition must be differentiated from the stenosing tenovaginitis or injuries to the carpal bones. In the majority of instances the onset is insidious and the course is characterized by pain over a period of from six to ten years. Apart from the aesthetic appearance of the thumb, the prognosis is not unfavorable. The pain usually disappears within several years. Treatment should consist of the general treatment of the degenerative arthroses,—iodine, sulphur, thyroid and ovarian extracts. Functional rest, actinotherapy, ionization, and diathermy have proved of some value locally.

In the very painful form the author has performed drilling, both of the trapezium and of the base of the phalanx, with some improvement.—*Henry Milch, M.D., New York, N. Y.*

L'ARTHROGRAPHIE DANS LA LUXATION CONGÉNITALE DE LA HANCHE (Arthrography in Congenital Dislocation of the Hip). Jacques Leveuf et Pierre Bertrand. *La Presse Médicale*, XLV, 437, 1937.

The authors report fifteen cases of congenital dislocation of the hip in which the arthrographic method was used for the purpose of determining the validity of closed reduction or the necessity for open operation. The technique used by the authors consists in the injection of from one to ten cubic centimeters of a 35-per-cent. solution of diagnorénol, or a 30-per-cent. solution of ténébryl. Because of the attendant pain, the authors advise the use of general anaesthesia in children or local anaesthesia (one to two cubic centimeters of novocain) in adults. The method is quite in line with that proposed by Bircher, Böhm, Marziani, Galland, and others. In the dislocated hips a cotyloid chamber and a cephalic chamber, separated by an isthmus, can be made out. The width of the isthmus varies, depending on the presence of adhesions, the size of the round ligament, shelf formation, etc. As in the hands of other workers, this method has proved of great value in establishing the true nature of the dislocation. The authors do not mention any ill results following the use of the interarticular medication.—*Henry Milch, M.D., New York, N. Y.*

SUR LE TRAITEMENT PAR LA SPLÉNECTOMIE DU SYNDROME DIT DE CHAUFFARD-STILL (Splenectomy in the Treatment of Chauffard-Still Syndrome). M. Loeper, André Lemaire, et Jean Patel. *La Presse Médicale*, XLV, 625, 1937.

The authors report a case of Chauffard-Still disease occurring in an adult, aged twenty-eight. There was a bilateral symmetrical deforming arthritis of the hand, with evidence of arthritic involvement of the wrists, knees, etc. Examination also showed marked splenomegaly, no leukopenia, and an enlargement of the regional lymph glands. Following splenectomy, the pains and functional impairment of the joints disappeared. Swelling became less, and the temperature fell to normal. The anaemia improved. Two weeks after operation a phlebitis of the left leg developed, which gradually subsided within three weeks. The patient died subsequently of a so-called grippal bronchial pneumonia. A discussion of the rôle of splenectomy in arthritis in general is given.—*Henry Milch, M.D., New York, N. Y.*

MYOSITIS OSSIFICANS PROGRESSIVA. E. A. Cockayne. *Proceedings of the Royal Society of Medicine*, XXX, 162, 1936.

The author reports the case of a female, aged twenty-three, with several congenital anomalies of the hands and feet, including shortened metacarpals and metatarsals, and some lengthened phalanges. The family history was negative. A year previous to examination she had had pain and swelling in both calves with no apparent cause. The muscles felt hard and tight, and she could not walk. The condition grew progressively worse and four months later she had had a hard, tender swelling, about two and one-half inches long, on the inner side of each gastrocnemius. A month later, a firm, tender, painful swelling had appeared on the lower part of the left soleus muscle; this had been followed in a few days by a larger swelling on the right soleus. Roentgenograms showed no evidence of bone formation in either gastrocnemius.

This case is one of myositis ossificans progressiva, diagnosed before actual ossification had begun. The etiology is unknown, but the presence of malformations of the metacarpals and metatarsals is established as part of the disease in most instances. The relationship between the two is obscure. The unusual feature of this case is the late onset of symptoms; the majority of cases appear in early childhood.

Treatment is speculative. Parathormone injections, to attempt the mobilization of calcium salts when detectable by the roentgenogram, are suggested, and, in addition, the simultaneous administration of acid sodium phosphate to keep up the blood phosphorus, since some degree of acidosis has seemed to help in the treatment of calcinosis.—*B. M. Halbstein, M.D., Iowa City, Iowa.*

OSTEOCHONDROSIS-OSTEOCHONDRITIS ISCHIO-PUBICA. A. A. Zeitlin. *Radiology*, XXVII, 722, 1936.

Through extensive investigations, the author has been able to "distinguish a special group of lesions in the osteochondral part of the epiphysis of growing bone, which are at present united under the name of epiphysitis or juvenile osteochondropathy". To the uncommon localization of this process belong lesions of the ischiopubic synchondrosis. He divides the cases into two groups:

1. Those with changes based on impairment of the normal process of ossification. This type he proposes to call "osteochondrosis ischio pubica".

2. Those characterized by an inflammatory reaction, and known as "osteochondritis ischio pubica".

Ossification of the ischiopubic cartilage occurs at about eight years of age.

Osteochondrosis shows in the roentgenogram a round or oval focus of rarefaction with distinct contours. Characteristic is the projection of the bony cartilaginous mass in the form of a triangular promontory in the lumen of the foramen obturatum. Strips of normal bone are left on the medial and lateral sides.

In cases of osteochondritis the process of decalcification and dystrophy is not limited to the synchondrosis, but is transferred to the adjoining parts of the os pubis and the os ischii, forming one continuous focus or appearing as a number of separate spots. The process is of longer duration, and in far advanced cases there may be considerable deformation.

The author discusses the differential diagnosis and reports some cases of both types. No biopsies are reported to verify the diagnosis.

The prognosis in both diseases is favorable and, while it is better in osteochondrosis, osteochondritis does not usually produce anything more severe than a deformity of the pubis.—*T. A. Angland, M.D., Iowa City, Iowa.*

ZERRUNGSSCHÄDEN DER KNIESCHEIBENSEHNE (Injuries to the Patellar Tendon Due to Strain). Alfred Saxl. *Zeitschrift für Orthopädie*, LXV, 129, 1936.

Repeated overstretching of the patellar tendon, due to excessive and forceful flexion

movements of the knee, is apt to produce a traumatic periostitis at the sites of attachment of the patellar tendon on the lower pole of the patella and the tibial tuberosity. The condition is characterized by pain and localized tenderness with or without swelling over the sites mentioned. Roentgenographic findings are completely negative. This condition must not be confused with Osgood-Schlatter disease, in which the age and positive roentgenographic findings are of definite aid in diagnosis. The condition is treated by immobilization of the knee in an elastic bandage with an attempt to push the patella downward, so as to relax the patellar ligament.

The author has observed this condition in five adults.—*Harold Unger, M.D., Iowa City, Iowa.*

Über die hintere Anschlagsperre des oberen Sprunggelenks (Posterior Bone Block of the Ankle Joint). W. Dega. *Zeitschrift für Orthopädie*, LXV, 236, 1936.

The author presents an analysis of twenty-two posterior bone-block operations.

Camera's interarticular technique was used in eleven cases. In this method a tibial graft is driven from above into the posterosuperior portion of the astragalus. The free end of the graft is only one centimeter in length and reaches the posterior inferior border of the tibia when the foot is at a right angle with the leg. The immediate functional results after this operation were good, but, from several months to several years later, the patients began to complain of pain, due to the arthritic changes in the lower end of the tibia and the free end of the graft. In several instances there followed an arthrodesis of the ankle; while in others the graft became detached from the astragalus and united with the lower end of the tibia. In the latter instances the results were not necessarily bad. Of seven follow-up examinations several years later, the results were excellent in only two, fair in two, and poor in three.

Gill's method was used in one case. The result is uncertain.

In the remaining ten cases the author used a modified Nové-Josserand extra-articular method, which is similar to Campbell's technique. Only one incision is used, which arches from above and behind to below and around the external malleolus. A triple arthrodesis is performed, but the posterior subastragalar half of the superior portion of the calcaneum is not resected. This portion is partially chiseled away from above and anterior to below and posterior. It is then pried posteriorly until it forms a right angle with the calcaneum, and is allowed to attach itself to the lower posterior surface of the tibia. Eight follow-up examinations, from several years to ten years after operation, revealed good functional results, with no pain, in all cases.—*Harold Unger, M.D., Iowa City, Iowa.*

Technik und Resultate meiner Pseudarthrosenoperation (Technique and Results of My Operation for Pseudarthrosis). Hermann Matti. *Zentralblatt für Chirurgie*, LXIII, 1442, 1936.

In 1929 the author described a new operative technique for pseudarthrosis. He now reviews the results obtained in fifty-five cases. Complete bony consolidation was obtained in fifty-two cases, or 94.5 per cent.

The following technique was used: Lateral incisions are made in the femur, in the humerus, and in the forearm, and an anterior oval incision in the tibia. In the latter, the incision goes immediately to the bone, so that periosteum and skin are not separated to obtain better nutrition. From the cleft, the anterior wall of both fragments is chiseled out for from six to eight centimeters. Excision of the fibrous-tissue disc between both fragments follows, except for a small bridge (two centimeters) which prevents lateral dislocation. The next step is a careful removal of the marrow and spongiosa by curettage. Experiments on animals show a marked stimulation and increase of endosteal-callus formation when the marrow and spongiosa are taken out. The whole excavation is then filled with small pieces of spongy bone. These are obtained by chiseling the greater

trochanter and removing the spongy material which can be found there in great amounts. In cases of pseudarthrosis of the tibia the material can be taken out from the tibial condyles. The spongy-bone pieces used to fill the hole are about one-half of a cubic centimeter in size and may be square or round in shape. If there are some spaces between them, they can be filled with bone chips from the previously removed compact bone. The wound is closed in the usual manner, without drainage. If hematoma occurs, removal by aspiration with a syringe is indicated. A plaster cast is applied, or extension is made with a wire or pin. The important advantage of the method over a bone graft is that it can be used also in cases of infection when one solid graft probably would fail to take. The average time required for complete bony healing to take place in adults was from eight to ten weeks in the tibia and from ten to twelve weeks in the femur. The author does not allow the patient to walk in the plaster cast until the roentgenogram shows at least a small calcified bridge between the fragments.—*Joseph Wolf, M.D., Iowa City, Iowa.*

ECHINOCOCCUS DES ILEOSAKRALGELENKES (Echinococcus of the Sacro-Iliac Joint). Kagalnitzky. *Zentralblatt für Chirurgie*, LXIII, 1705, 1936.

The author describes an echinococcus cyst in the sacro-iliac joint, a localization until now not recorded in the literature. The patient was a laborer, thirty-two years old. Five years ago he had noticed a slowly growing tumor over the left sacro-iliac joint, which had rapidly increased in size during the past year. At operation, a tumor the size of a man's fist was found, containing many living and dead echinococcus cysts. Complete healing took place.—*Joseph Wolf, M.D., Iowa City, Iowa.*

WIE ENTSTEHEN PSEUDARTHROSEN UND ANDERE MISSERFOLGE NACH NAGELUNG MEDIALER SCHENKELHALSBRÜCHE (How Do Pseudarthroses and Other Bad Results Occur after Nailing of Medial Fractures of the Femoral Neck)? Fritz Felsenreich. *Zentralblatt für Chirurgie*, LXIII, 2843, 1936.

Most observers believe that shearing stresses play the greatest rôle in the production of pseudarthroses after nailing in medial femoral-neck fractures. The nail, centrally placed, but lying in the cranial quadrant of the femoral head, is forced upward under shearing stresses and finally works its way through and above the head. This results in a sinking and a varus deformity of the femoral head, the outcome of which is pseudarthrosis.

On more careful observation, however, one discovers that there is a more important factor in the production of pseudarthrosis than that attributed to shearing force. Many investigators have frequently observed a progressive external rotation of the femoral shaft, beginning ten to twenty days postoperatively, usually as a result of motion. Concomitant with this external rotation of the shaft, there is also an independent clockwise rotation of the femoral head about a transverse frontal axis. These processes are apt to occur most frequently when the nail lies in the anterior segment of the femoral head and less frequently when it is placed in the lower and posterior segments of the head. This rotation of the head inevitably results in a sinking and a varus deformity of the head and thus in a pseudarthrosis.

In the four cases observed by the author, the latter factor was responsible for the non-union. In Nyström's series of twenty-nine cases of pseudarthrosis practically the same percentage was also attributed to this factor.—*Harold Unger, M.D., Iowa City, Iowa.*

ZUR OPERATIVEN BEHANDLUNG DER HABITUELLEN LUXATION DES SCHULTERGELENKS (The Operative Treatment of Habitual Dislocation of the Shoulder). Hermann Matti. *Zentralblatt für Chirurgie*, LXIII, 3011, 1936.

The author makes a pectorodeltoid incision. The subscapularis tendon is freed and

divided close to its insertion on the lesser tubercle of the humerus. The anterior relaxed portion of the capsule is picked up as a fold and sutured to the remaining attached stump of the subscapularis tendon. By means of a chisel, a periosteocortical flap is reflected from the greater tuberosity just external to the intertubercular sulcus. The arm is rotated internally, and the subscapularis tendon is pulled laterally and anchored with silk under this osseous flap. A nail may be used for further fixation of the flap and tendon against the humerus. The arm is immobilized in internal rotation for three weeks.

This operation was carried out successfully on twelve patients; however, not enough time has elapsed for a permanent end-result evaluation. In all the patients a partial limitation of external rotation developed after this operation. This the author regards as a safeguard against relapse.

This operative procedure is a slight modification of the de Quervain method, in which the transplanted subscapularis tendon is simply sutured subperiosteally to the greater tuberosity of the humerus.—*Harold Unger, M.D., Iowa City, Iowa.*